THE ECONOMIC UTILISATION

of

TOWN REFUSE

by

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INTRODUCTION.

In this paper I propose dealing with two distinct methods of extracting revenue from the disposal of town refuse in Scotland.

The period under discussion is the decade commencing in 1920 which may be considered as the evolution of the present established system.

The plants to be dealt with were situated in Falkirk, Blackhall and Powerhall, the last two being in the City of Edinburgh and it is from the results of these plants that a more or less stabilised method of treatment has been evolved and can be examined in operation at the Cleansing Departments of Perth, Dundee and Aberdeen.

I write with authority on the plants illustrated and described as I was assistant manager in the firm who manufactured them and had charge of the erection of each in turn from its commencement when the design was under discussion to the final handing over as completed, to the respective Corporations.

References to other plants and such statistics as are given were obtained from the following standard works on the subject.

Goodrich   Refuse Disposal and Power Production (Archibald Constable & Co. 1904).

Thomson   Modern Public Cleansing Practice (Sanitary Pub. Co. Ltd., 1928).

Jas.Jackson Study Circle Public Cleansing
(Ernest Benn 1929).

"The Burning of Town Refuse". Proc. Inst. of Mech.Eng. by Geo.Watson, Member of Leeds.

"Refuse Destruction by Burning and Utilisation of Heat Generated"
by C.Newton Russell, Burgh Electrical Engineer, Shoreditch, London.

Goodrich "The Utilisation of Low Grade and Waste Fuels"
(Ernest Benn Ltd. 1924).

I would tender thanks to Mr.Macrae, City Architect, Edinburgh, Mr.Kinnear, Civil Engineer, Edinburgh Corporation, Mr.Beveridge and Mr.Wilson, late and present Inspectors of Cleansing, Edinburgh Corporation, Mr.Rae, Inspector of Cleansing, Burgh of Falkirk, Mr.Climie, Electricity Manager, Burgh of Falkirk, Mr.Sagar, Inspector of Cleansing, Burgh of Dundee, Mr.Cuthill, Mechanical Engineer, Dundee Corporation, and Mr.Finlay, Inspector of Cleansing, Burgh of Aberdeen, fortheirkind help and assistance during my investigations both at the time of erection of these plants and subsequently when test results were being investigated.

BURGH OF FALKIRK REFUSE HANDLING PLANT.

The problem of economically handling the shop and domestic refuse in the Burgh of Falkirk came up for serious consideration by the Town Council in 1920 when the Cleansing Inspector, Mr.Rae, put forward a scheme of mechanical sorting for saleable disposal which, although revolutionary in Scotland had been employed with success in America for many years.

The existing method was simple but expensive, consisting of the maintenance of a crude refuse dump in the country to which all town refuse was railed. The transport costs and handling costs at the dump were very considerable, especially at this time when freights and wages were high and the calculated saving taken on the ruling prices for scrap of all kinds showed a very marked reduction in the cost of refuse collection.

Mr.Rae's scheme was to separate the refuse into three grades, the finest to be sold to farmers as manure, the second to be known as cinder and sold to the Electricity Department as fuel and the remainder to be sorted out and various articles such as tins, bottles, rags etc. salved, to be sold separately to scrap dealers.

The success of such a scheme hinged on the fuel value of the middle grade and its behaviour in modern furnaces, and tests carried out on a small scale with hand riddling had demonstrated the great possibilities which lay in this direction.

The plant as originally erected consisted of a rectangular steel framed building with ridged roof, the whole being covered in corrugated iron sheeting.

The refuse from the collecting vehicles was elevated and discharged into a revolving riddle below which a nest of hoppers stored the riddlings; the remainder passed down a chute from the front of the riddle on to a belt picking table.

The refuse passing along this moving belt had various saleable articles removed by hand picking and the tailings passed over the end of the table to discharge into a waiting vehicle for removal to the railway siding and thereafter to the country dump.

Carts were able, owing to the configuration of the ground, to stand below the hoppers underneath the riddle and in this way the fines were removed for sale as manure and the cinders for sale as fuel.

CRUDE REFUSE HOPPER AND ELEVATOR.

It is very doubtful whether a completely successful crude refuse elevator can be produced as the material is so heterogeneous in character that it is impossible to make adequate provision for dealing with the extremes to be met with.

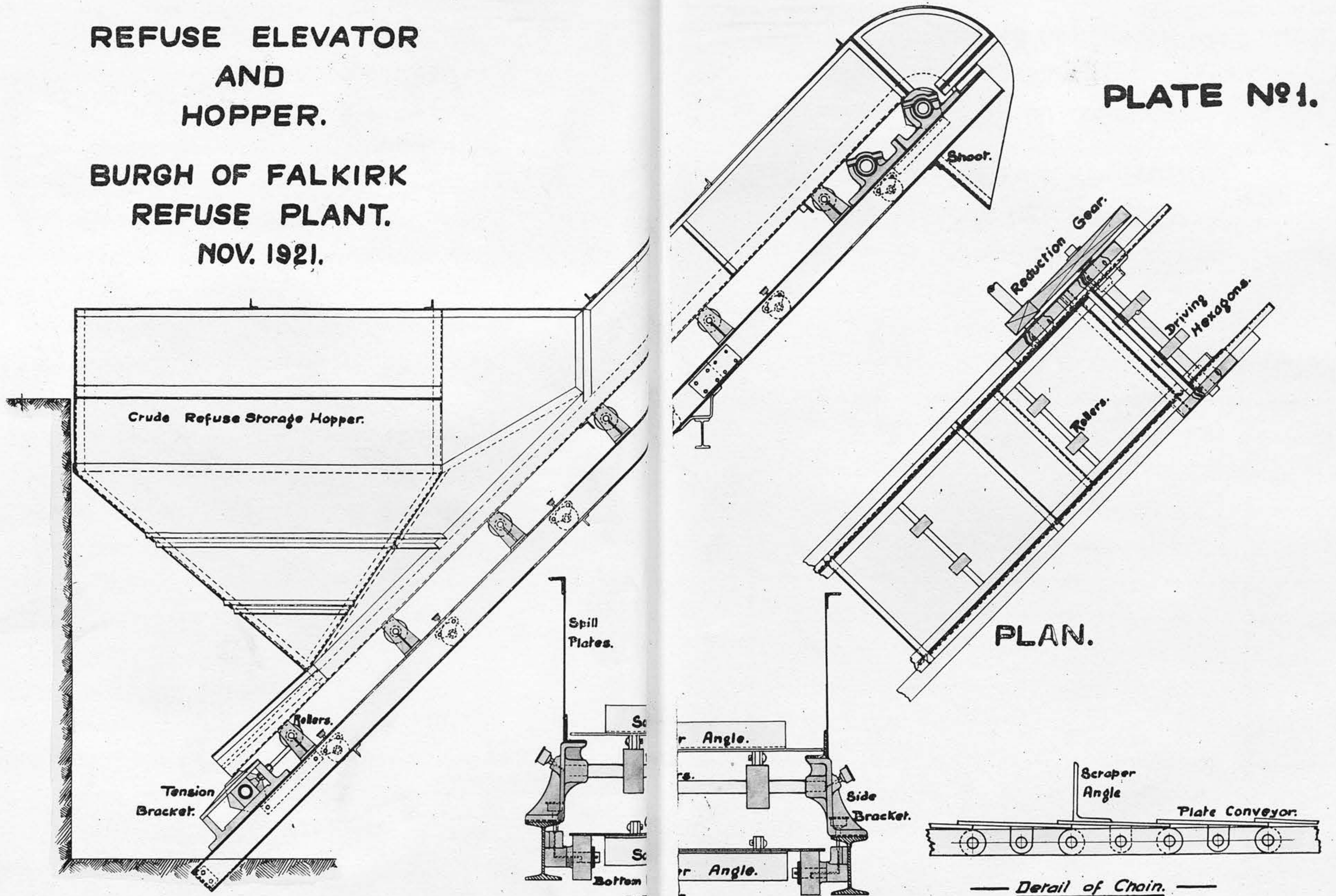
Plate I shows the means adopted. The

REFUSE ELEVATOR AND HOPPER.

BURGH OF FALKIRK REFUSE PLANT.

NOV. 1921.

PLATE No. 1.



SIDE ELEVATION.

SE TION.

PLAN.

— Detail of Chain. —

collecting cart tipped into the hopper from which the refuse was expected to feed on to the elevating belt. It was found necessary to employ a man constantly at this point as a certain amount of arching took place and delivery up the elevator would cease. It was necessary also to guard against unsuitable articles being tipped and the man at the tipping point was expected to remove anything likely to jamb or damage the machinery of the plant.

The elevator consisted of a special type of plate table set at an angle of 45^{o}, the plates forming the moving band being 3 feet wide and 8 inch by $\frac{1}{4}$ inch section. These were mounted on a double link chain carried on double rollers and hexagon drums at top and bottom. Angles 4 inch by 3 inch section were spaced across the moving plates at intervals to prevent the refuse falling back and strips of greenheart wood were fitted to the upper guide angles to form a rubbing strip for the edges of the moving plates and act as a dust seal, so that the exposed links of the carrying chains would be, as far as possible, protected against wear.

The fitting of these hardwood strips was not a success as they wore out in a short time and a considerable amount of fine dust found its way on to the under side of the moving belt and caused very rapid wear on the chain links which needed frequent renewal.

REVOLVING RIDDLE.

The separation of fines was carried out by a riddle of the type in common use at collieries for screening coal with the exception that, on account of its size and weight, it was carried on rollers (Plate 2) and the thrust due to its slope was taken by thrust rollers supporting the end ring (Plate 3).

The riddle was of massive construction and comprised a double perforated shell which extended for two thirds of its length. The interior was provided with longitudinal baffles designed to lift and turn over the contents during their passage through the machine and so ensure complete separation.

The first perforation consisted of $\frac{3}{4}$ inch mesh and this separated the finer cinder and dust which dropped through to the outer shell of $\frac{3}{8}$ inch mesh. The second perforation on the main shell was of $1\frac{1}{2}$ inch mesh and the contents remaining were fed by a short chute on to the picking table.

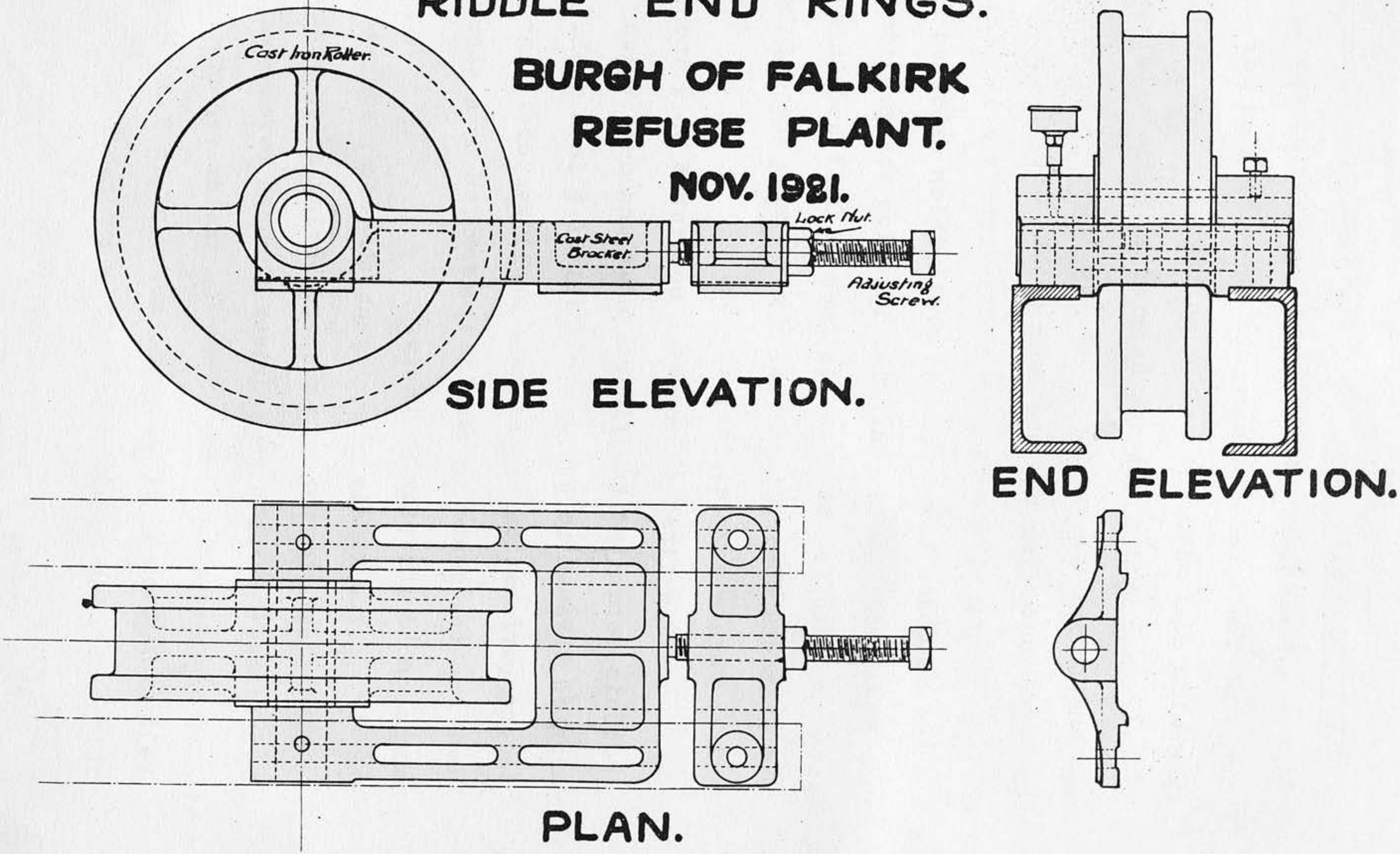
The riddle end ring at the upper end was provided with 2 inch pitch spur gearing which meshed with a cast steel pinion driven through bevel wheels from the main shaft which in turn was driven through belt reduction by an electric motor of 15 Horse Power. This one motor provided all the power required for

PLATE Nº2.

ROLLER MOUNTING CARRYING RIDDLE END RINGS.

BURGH OF FALKIRK REFUSE PLANT.

NOV. 1921.



driving the plant.

Three Hoppers were arranged below the riddle to form storage for:-

(1) Dust, up to $\frac{3}{8}$ inch.
(2) Small Cinder, $\frac{3}{8}$ to $\frac{3}{4}$ inch.
(3) Large Cinder, $\frac{3}{4}$ to $1\frac{1}{2}$ inch.

In the layout of the plant use was made of the sloping character of the site and it will be seen from Plate 1 that there is a considerable distance from the discharge from the elevator to the low ground level. This distance was sufficient to enable carts to stand for filling below the nest of hoppers which were provided with a sliding type of bottom door controlled through rack and pinion gear operated by a hanging chain from the low ground level.

The end chute from the riddle discharged on to a Belt Picking table shown in Plate 4.

This consisted of a wooden framework carrying the supporting rollers with side strips to prevent spill. Plate 5 shows a section of the machine which was of simple construction and, apart from the initial cost of the rubber composition belt, of low first cost. Girl pickers standing on either side of the machine removed such articles as were being salved for after-sale.

Bags hanging from the roof of the compartment under the picking house received the salved material which was fed to them through traps in the picking house floor.

The tailings from the picking table passed down a chute on to a cart standing below the gable end of the building.

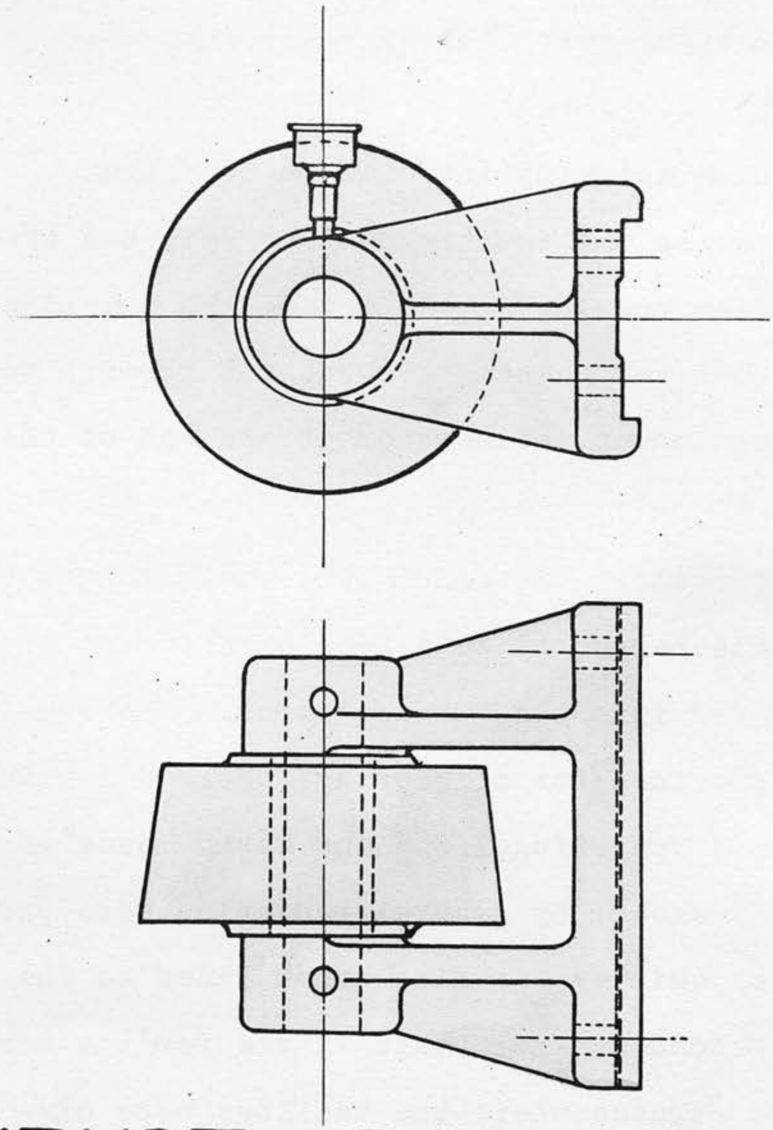
It was originally intended to have these tailings conveyed to the country dump by rail but after the plant had been running for some time the question of incineration arose and Heenan & Froude put forward two schemes for erecting an incinerator at the end of the picking house.

Plate 6 shows the original proposal where the tailings were discharged on to a feeding floor on ground level and hand-fed into the furnace through the same doors as were provided for clinkering. Forced draught was supplied by a centrifugal fan and as no means of heat dissipation except by natural radiation were provided, the steel chimney was fire brick lined to the top.

The second scheme, Plate 7, was for the more modern top feed furnace where the tailings were discharged on to a platform above the furnace which was provided with a circular door in the arched roof so that refuse could be fed in by gravitation and less handling would be entailed. The blower fan in this case would probably require to be shut down during feeding to prevent the flames rising up through the top openings.

A water trough with baffle wall was provided

PLATE Nº3.



THRUST ROLLER

FOR

RIDDLE.

BURGH OF FALKIRK

REFUSE PLANT.

NOV. 1921.

J. Storie Carswell.

in the main flue to collect as much dust as possible from the chimney gases and prevent nuisance arising which might cause complaint from the surrounding property owners.

This method of treating the tailings had much to recommend it and the only material left to be removed by rail to the country dump was the clinker which formed a very small percentage of the input.

The plant was designed to handle 50 tons of crude refuse per day and gave very good service when one bears in mind the fact that it was a pioneer effort in Scotland and was the only one of its type erected; all the castings being made from special patterns produced for the purpose, no existing designs being adapted to suit.

The only weaknesses which became apparent were:-

(1) The elevating of crude refuse was expensive on account of tear and wear in the machine.

(2) A man was required at the tipping point; this was originally expected to be self feeding.

(3) The separation by riddle was satisfactory up to a point but, as might be expected, there was a proportion of vegetable matter present in the cinder and, large as the riddle was, it could not cope with the periodic output of the elevator, so a quantity of dust and fine cinder would find its way into the hopper for large cinder; also an incomplete separation was often noticed at the discharge shoot on to the picking table.

(4) The Belt picking table was silent in operation but the speed was far too low for the satisfactory working of a belt as a conveyor and considerable tension was required to prevent slipping.
Paper /

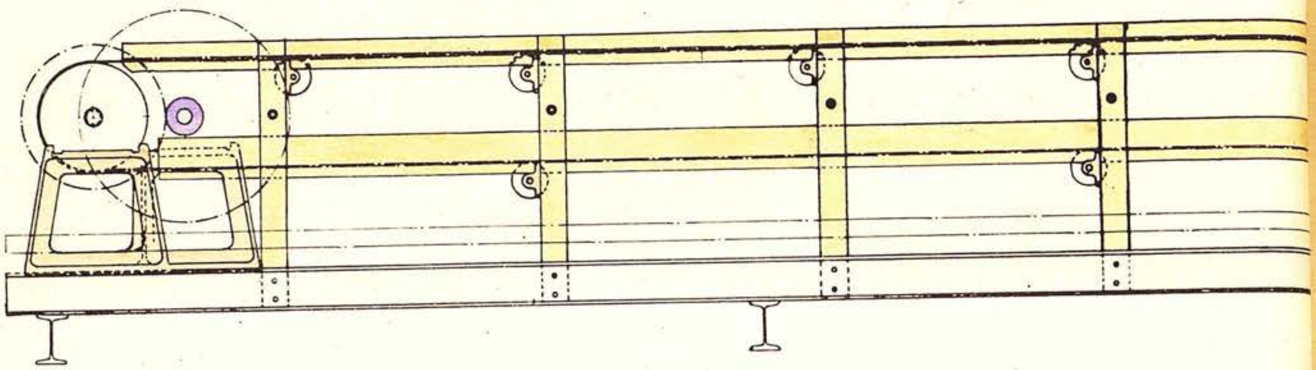
Paper and rags would find their way to the inside of the machine and be carried on to the end drums, where they spread out on the drum surface and there accumulated until the gradual enlarging of the drum diameter produced a belt tension which caused overheating at the shaft journals.

(5) The hoppers under the Riddle were too small and frequently their contents had to be discharged on to the ground if no cart was available This meant that the next cart must be hand fed until the heap on the ground was sufficiently reduced to allow a cart to take up its correct position under a hopper door.

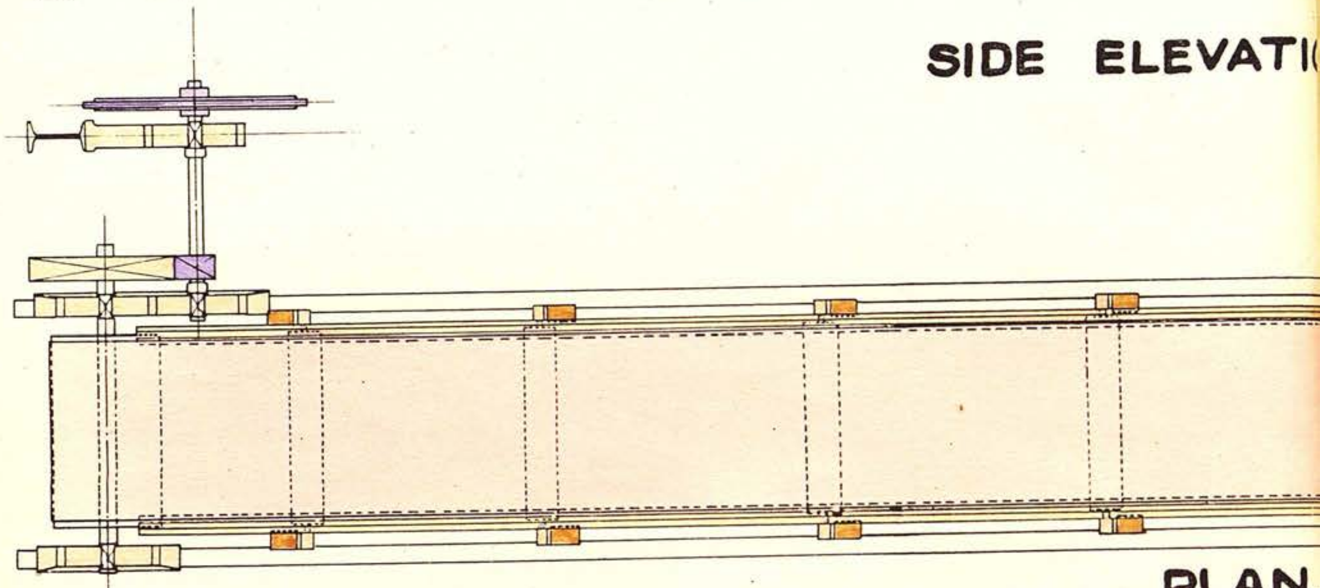
(6) The discharge of tailings over the end from the picking belt was never a success as these consisted principally of light combustible material such as paper, rags etc. which blew about and fouled the site.

The foregoing weaknesses were to some extent, gradually remedied. A secondary separation was arranged for the cinders, consisting of a second riddle mounted separately over a nest of large hoppers whose capacity was sufficient to cope with the time intervals between emptying. This riddle was fed from an elevating conveyor which lifted the cinder from the first separation to a point high enough to discharge into the second riddle. It was, however, unfortunate that only by the addition of more machines with their attending wear and depreciation could the difficulty be removed.

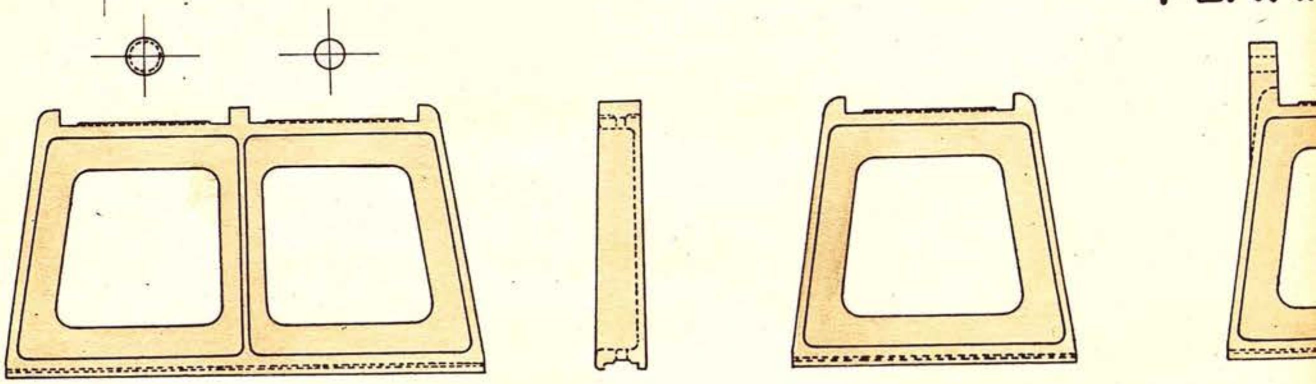
The /



SIDE ELEVATI

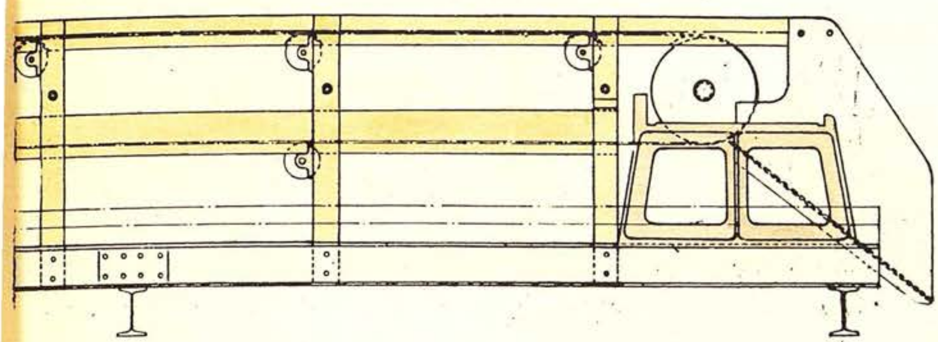


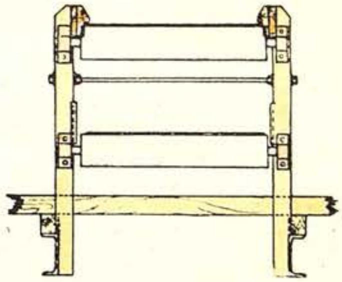
PLAN.



CAST IRON BRACKETS CARRYING R

PLATE Nº4.





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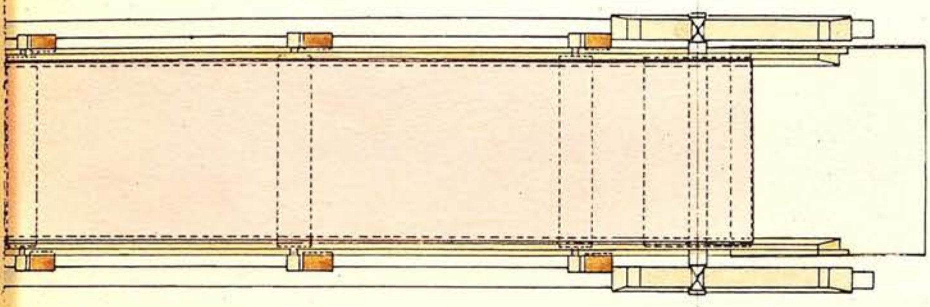
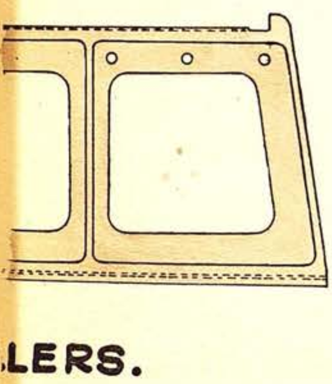
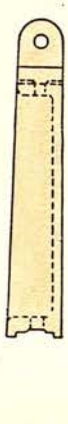
SECTION.







BELT PICKING TABLE
FOR
BURGH OF FALKIRK
REFUSE PLANT.
NOV. 1921.

LERS.

The Cost of the Falkirk Plant was:-

Plant, Buildings, Foundations etc.	£4292. 1. 3	
Forming Road of Access	518. 6. 0	
Purchase Price of Ground	820. 0. 0	£5630. 7. 3
Less ground sold	£ 400. 0. 0	
Recovered from Road of Access	185.14. 6	585.14. 6
		£5044.12. 9

It must be realised that if this method of handling town refuse is to be an economic proposition a revenue account of considerable size will be necessary to reduce the interest and depreciation on the capital and the labour and maintenance cost of operating the plant.

I have worked out average monthly returns of weight and value from figures supplied by Mr.Rae on results taken from the time I handed over the plant as completed up to the beginning of 1925.

The revenue which was slightly over £1000 per annum seems very satisfactory but it must be remembered that at that period prices were good and at the present day nothing like the figures shown can be expected from much of the material.

Material /

Material.	Weight per Month.	Approx.Value per Month
Dust	93.8	£8.55
Cinders	204.8	46.6
Tins	4.58	5.79
Metal	1.97	5.22
Paper	9.5	4.46
Sweepings	13.2	1.61
Bagging	1.3	.82
Cottons	1.27	2.15
Woollens	.212	3.15
Cullet	.79	.39
Bones	.667	3.39
Bottles	.667	1.94
	332.756	£84.07

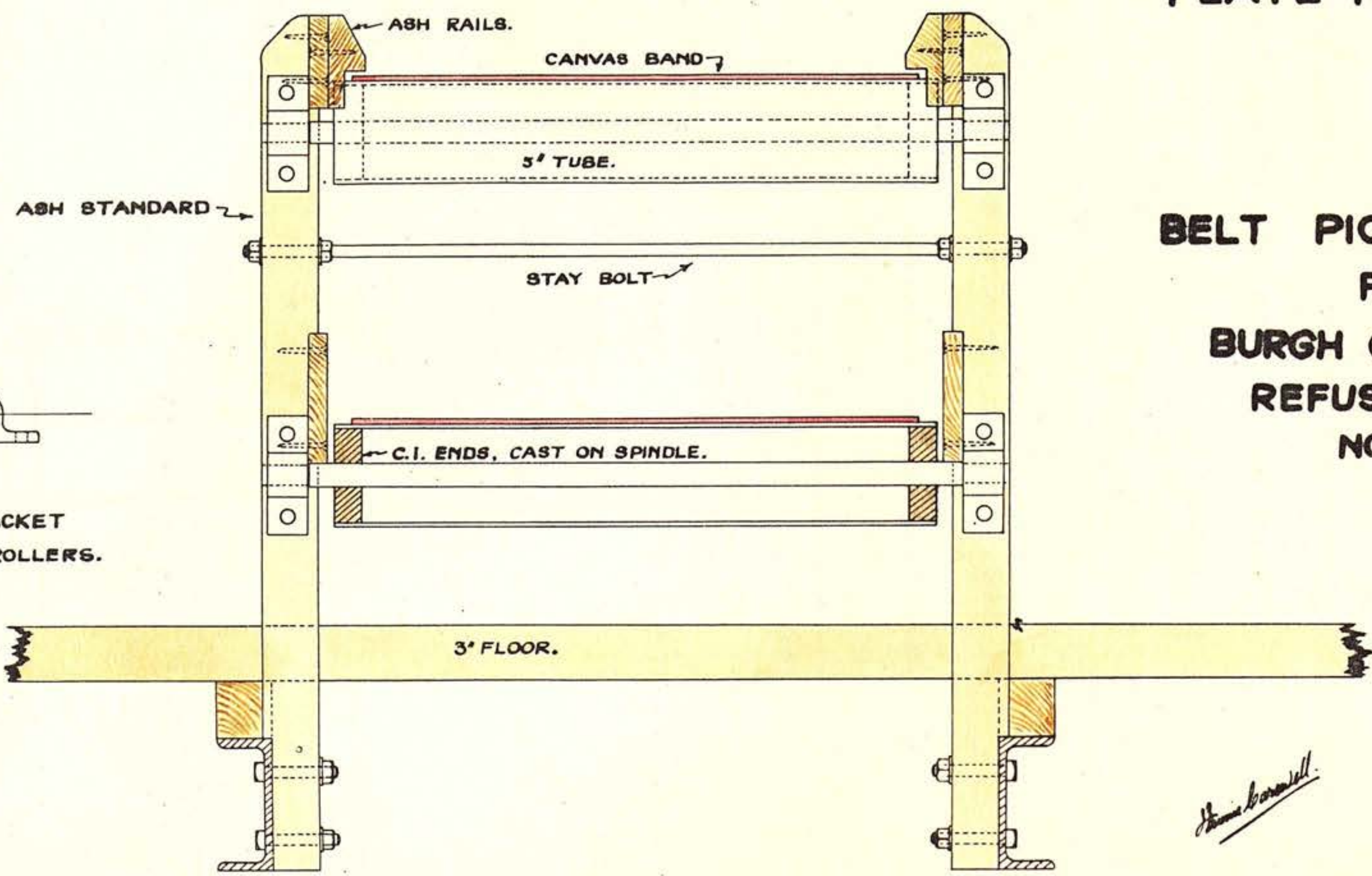
It will be seen from the above that the principal item of revenue is from the Cinders and in view of their importance I will deal with them more fully after discussing the first product of separation i.e. Dust which comprises nearly 40% of the total.

(1) Dust. The results of sieving tests and analysis of two samples taken, showed:-

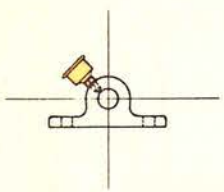
No.1 /

PLATE Nº5.

BELT PICKING TABLE
FOR
BURGH OF FALKIRK
REFUSE PLANT.
NOV. 1921.



SECTION.



SIDE BRACKET
CARRYING ROLLERS.

		No.1	No.2
Passed through 200 mesh		12.7%	21.9%
" " 150 "		5.3	4.9
" " 100 "		8.0	12.7
" " 50 "		14.5	16.3
" " 1/32" "		17.0	16.2
" " ⅛" "		32.0	19.9
Retained on ⅛" "		10.5	8.1
		100.0	100.0

The Analysis showed	No.1	No.2
Mineral Matter	55.56%	53.37
Organic "	26.51	31.14
Moisture	17.93	15.49
	100.00	100.00

It contained on the average 2% phosphates and ½% potash. The high percentage of organic matter and moisture made the small cinder content of little value from a combustion point of view, although a test of this cinder showed a Calorific Value of 7,500 B.Th.U. and if a system of covered Dust Bins had been in force it is probable that more of this dust might have been recoverable as a fuel.

It was hoped at the outset that a market would be found among local farmers for the fine dust and a small quantity actually was sold, but it was found only of value in breaking up an exceptionally heavy soil and the easily handled artificial manures now obtainable offer such advantages that farmers cannot be expected to substitute for them the bulky and disagreeable residue from refuse riddlings.

It is hoped that some outlet may be found in the future for this material in road making but during the life of this plant it was mixed with the picking belt tailings and sent to the dumps.

(2) Cinders.

These comprise nearly 40% of the refuse collection and it was from them that the greatest revenue return was expected.

The sale of cinders which is merely the term given to town refuse which has passed through a mesh of $1\frac{1}{2}$ inch and over a mesh of $\frac{3}{8}$ inch, is very difficult on account of:-

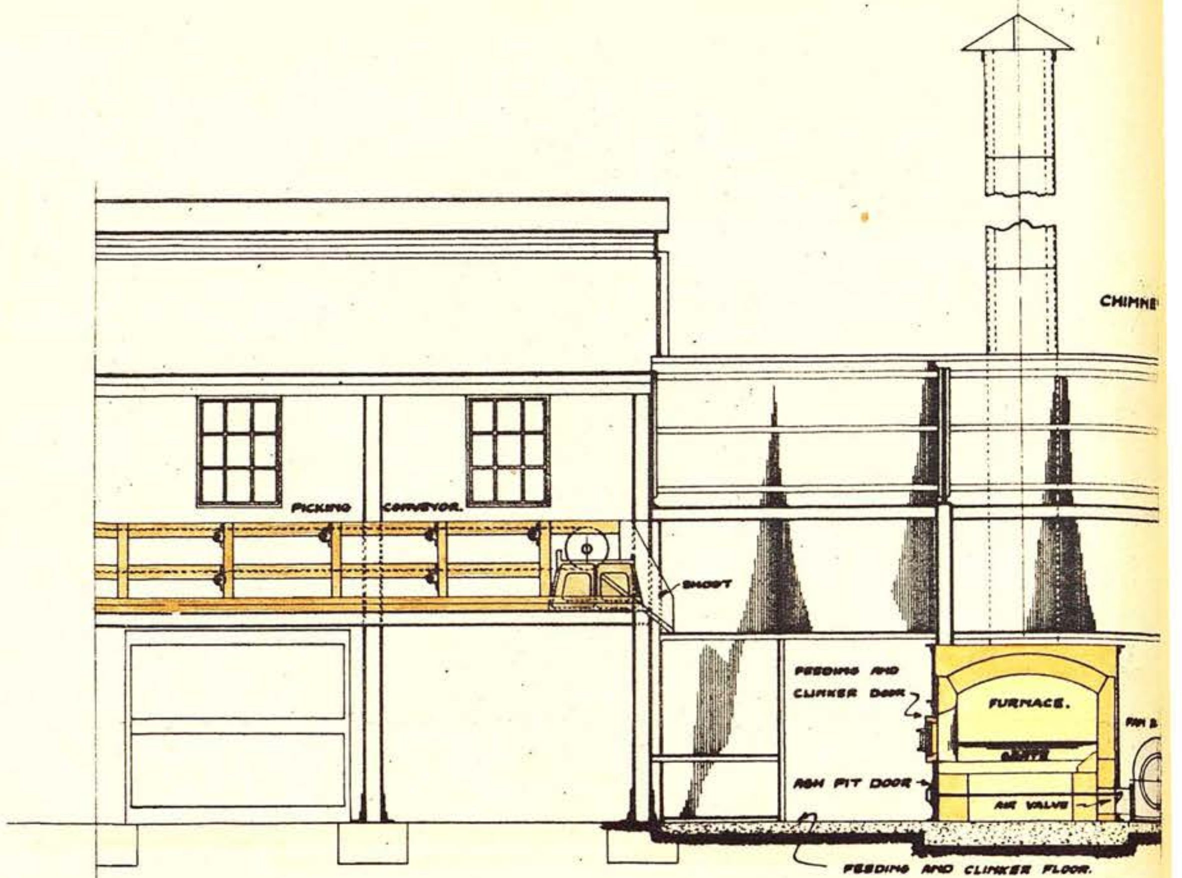
(a) The appearance.

(b) The curious odour when freshly separated.

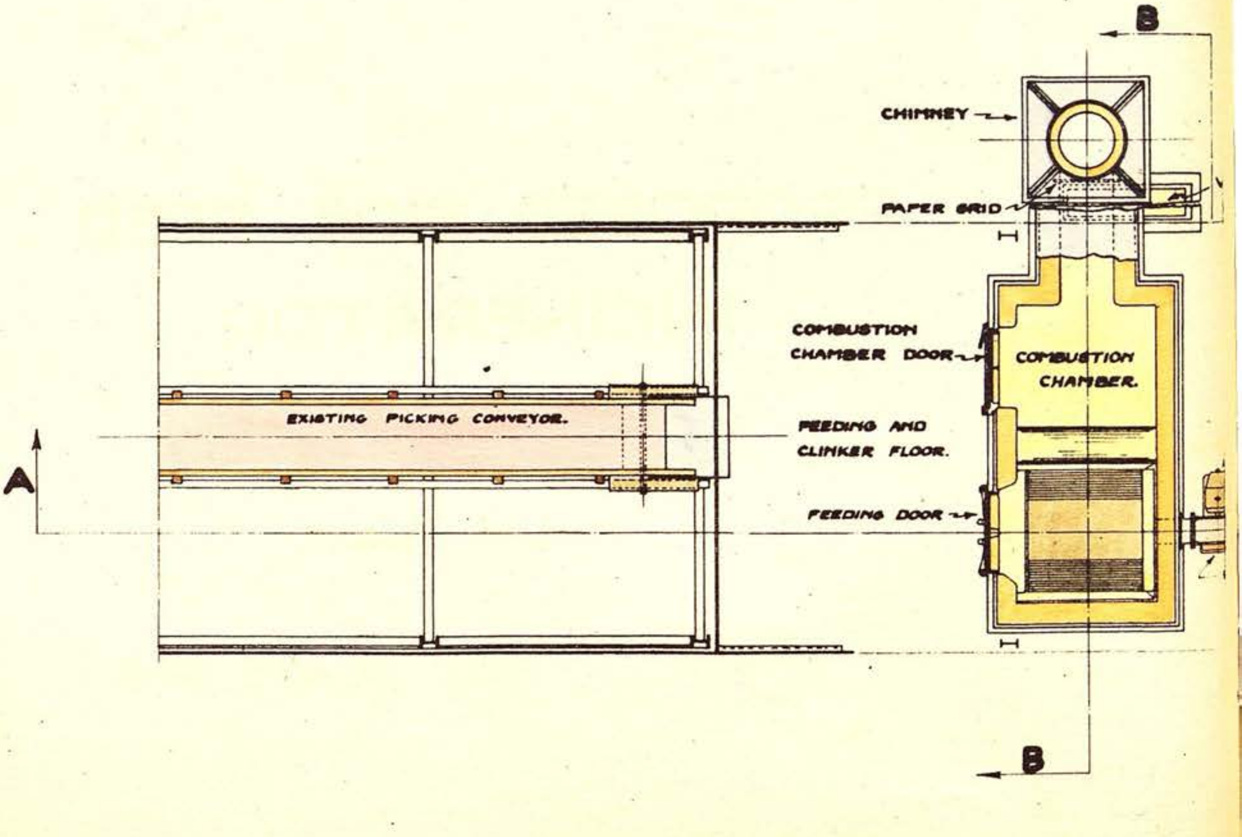
(c) The vegetable matter present causing heating on decomposition.

(d) The odour after decomposition has set in.

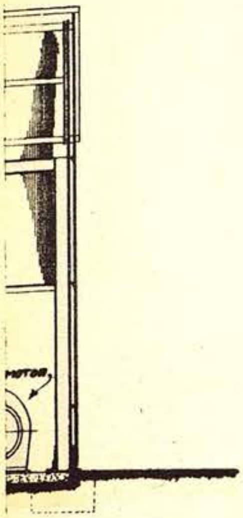
These faults are not very serious ones except that they detract from the selling value of the material and in the present case they were overcome by selling the whole cinder content to the Electricity Department as a fuel.

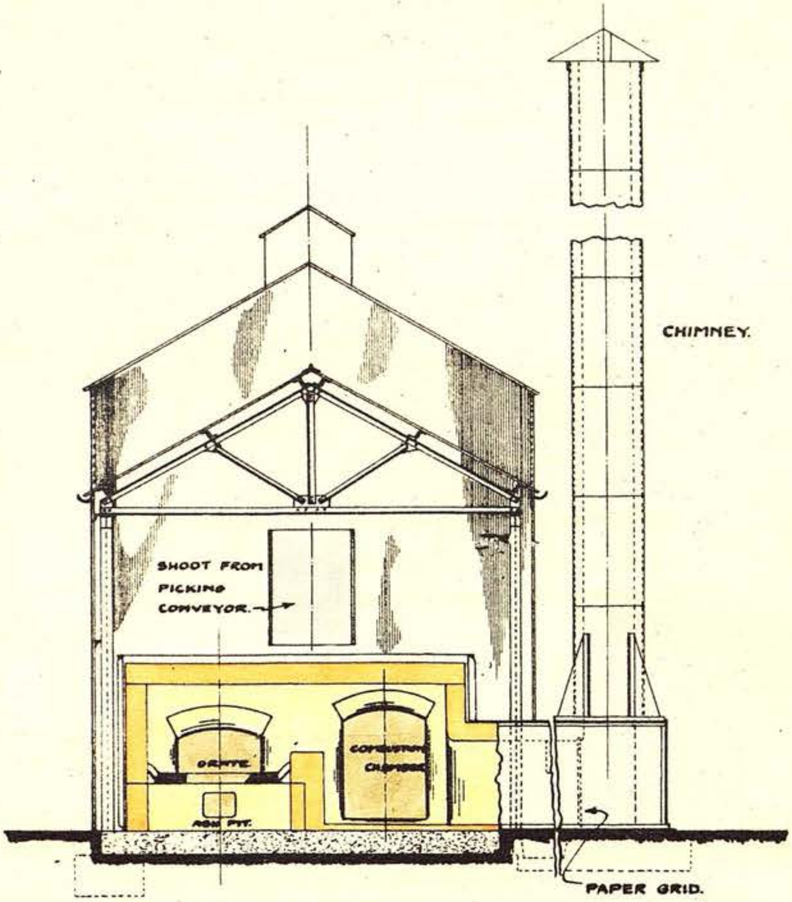


SECTION A.A.

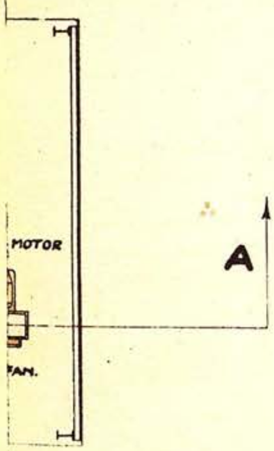


PLAN.





SECTION B. B.



PROPOSED SIDE FEED INCINERATOR

FOR

BURGH OF FALKIRK REFUSE PLANT.

PLATE Nº 6.

This was the essence of the Falkirk scheme and on the success of this fuel depended the success of the project.

The following Laboratory Tests by the Electricity Department give an idea of the heat value of the cinder compared with average coal.

Sample No.1.

This was a sample taken and washed in water. It contained cinder and ash to about 96.5% the remaining 3.5% being made up of small pieces of wood, paper, leather, straw, glass, iron etc. etc.

The Analysis gave:-

	Sample as Received.	Sample Dried.
Fixed Carbon	50·01	64·54
Volatile Matters (Gas, Tar etc.)	7·50	9·68
Ash	19·99	25·78
Water	22·50	-
	100·00	100;00
Calories	4,808	6,385
B.Th.U.	8,654	11,493
Evaporation per lb from and at 212°F.	8·97	11·91

Sample No.2.

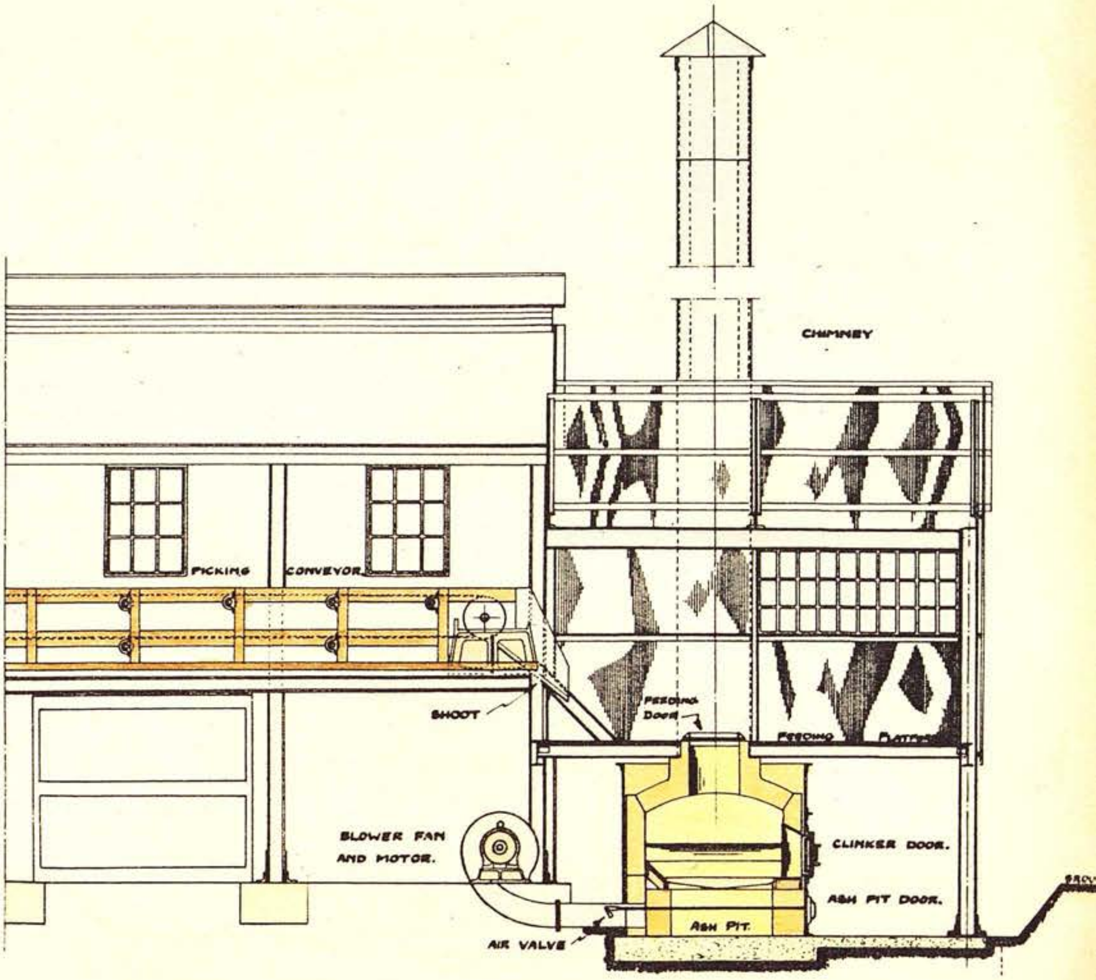
This consisted chiefly of cinders to about 89.5%, the remaining 10.5% being made up, as before, of small pieces of leather, wood, straw, paper, iron etc. etc. The sample was analysed in its normal damp state immediately after separation.

The Analysis gave:-

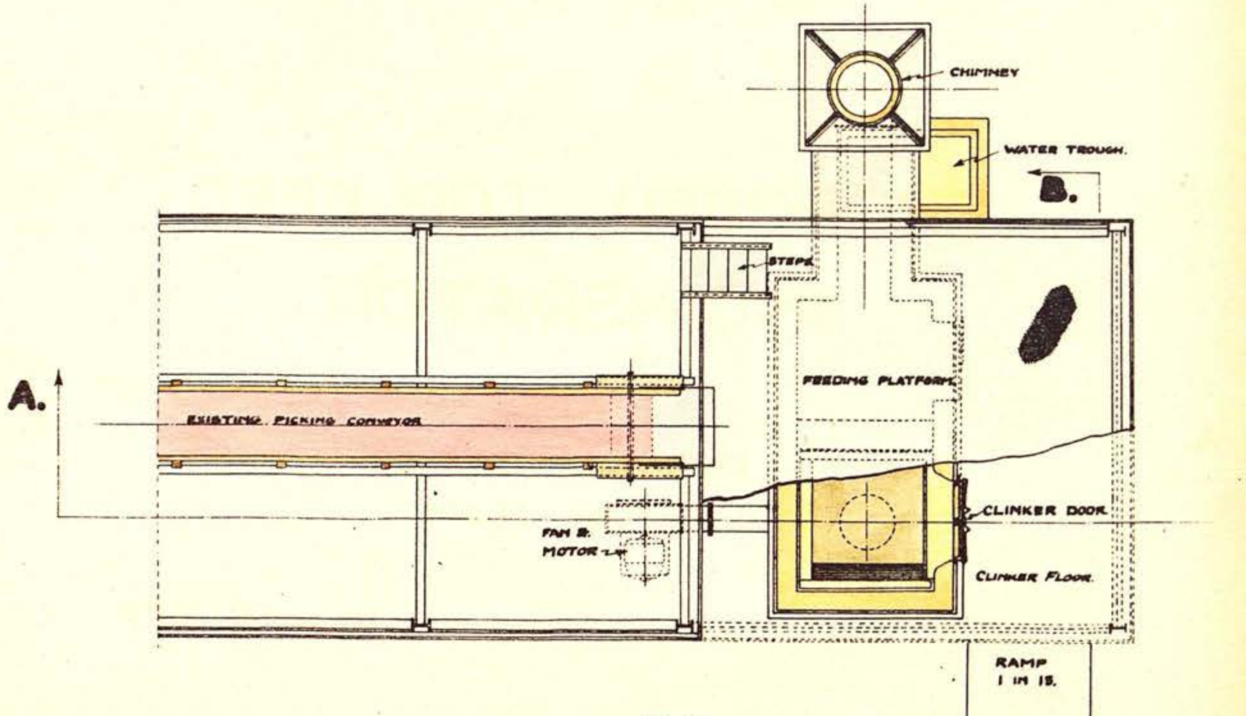
		Sample as Received.	Sample Dried.
Fixed Carbon	...	47·10	50·86
Volatile Matters (Gas, Tar, etc.)		10·13	10·94
Ash	...	35·37	38·20
Water		7·40	
		100·00	100·00
Calories	...	4,824	5,260
B. Th. U.	...	8,684	9,468
Evaporation per lb. from and at 212°F.	...	8·99	9·81

To enable a comparison to be made, the following is offered as an average analysis of reasonable quality coal.

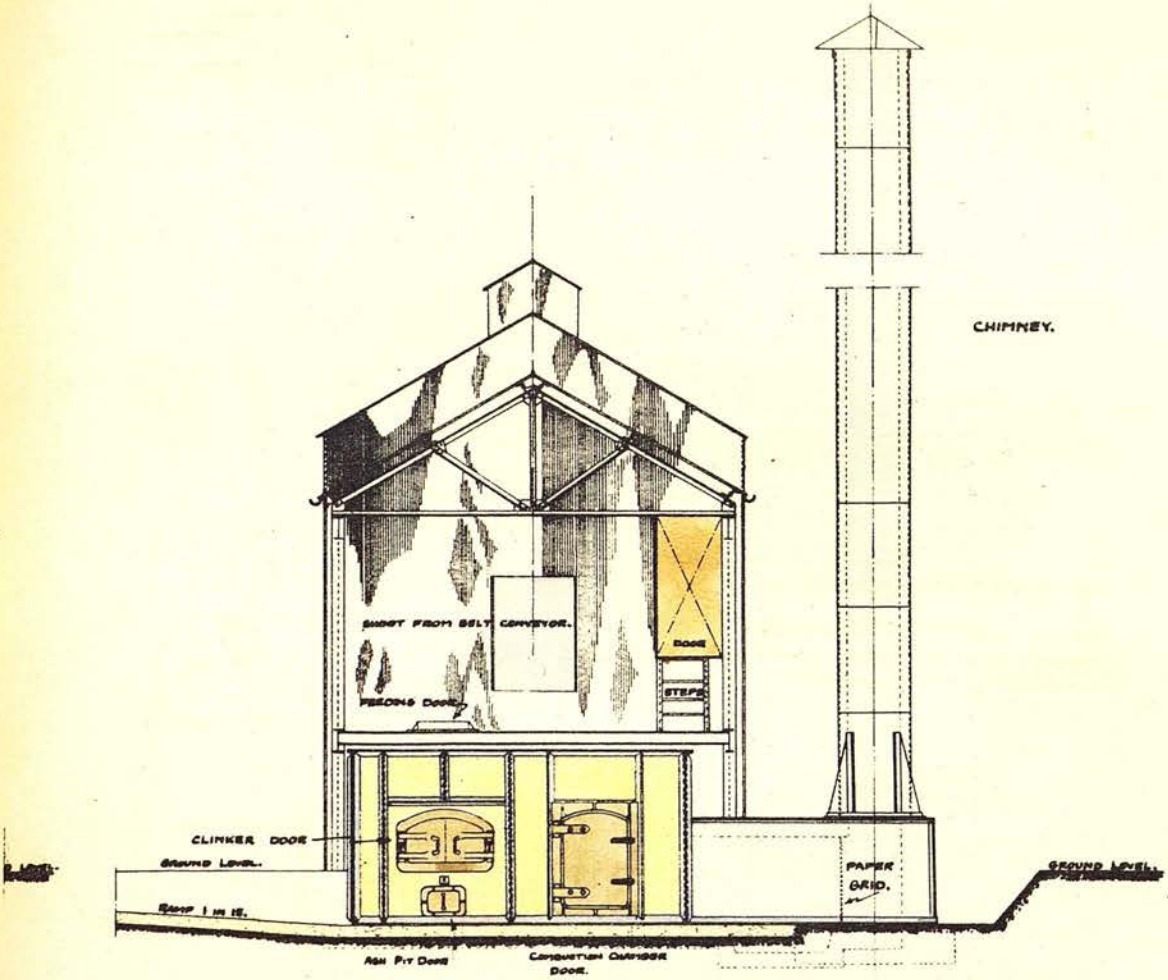
		Sample as Received.	Dried Sample.
Fixed Carbon	...	51·59	56·03
Volatile	...	30·34	32·95
Ash	...	10·15	11·02
Water	...	7·92	-
		100·00	100·00



SECTION A . A.



PLAN.



FRONT ELEVATION B.B.

PROPOSED TOP FEED INCINERATOR

FOR

BURGH OF FALKIRK REFUSE PLANT.

A.

PLATE Nº 7.

The low volatile content of the cinder is notable, showing its value as a smokeless fuel and the necessity of providing forced draught for its combustion.

This low volatile indicates the advisibility of mixing the cinder with coal gum or pearls and this is what is now being done and it is found that excellent results are obtained by an equal mixture of cinder and washed pearls: the cinders with their low volatile, opening up the mixture to allow perfect combustion and preventing any coking tendency of the fine coal.

The results obtained at the Electricity Department showed that this fuel mixture, even with a high volatile coal, gave practically smokeless burning and that it could be used in standard plant designed to burn low grade fuel.

The grates used were standard under feed, Class "A", with a forced draught fan supplying air at a pressure of ½ inch to 1½ inch W.G. under the grate.

It is obviously impossible to give a colorific value for the separated Cinder as it is heterogeneous and variable but repeated tests were taken at the Electricity Works when the question of what the Electricity Department should pay the Cleansing Department for the fuel was being settled.

These tests showed that in some cases the heat value rose to as high a figure as 10,000 B. Th. U. and fell as low as 6,000 B. Th. U.

The average value was finally recognised to be 8,500 B. Th. U.

This value was extremely high; a comparative value is offered in the figures over one year from New York City.

Extract from Trans. Am. Soc. C.E., Fetherston 1908.

New York City 1905.

Coal and Cinders (Average of 7 samples)			Percentage by Weight.
Moisture	...	...	1.65
Combustible (including volatile)		...	44.29
Ash	...	...	54.06
		Total	100.00
Calorific Value in B.Th.U. per lb.			4,901

Comparative results are also available from other American Cities.

From Record of Ohio State Board of Health 1910.

Cincinnati 1909-10.

Cinders (average of 7 samples)		Percentage by Weight.
Moisture	...	7.8
Combustible (including volatile)	...	30.5
Ash ...	...	61.7
	Total	100.0
Calorific Value B.Th.U. per lb.		3,087

Cleveland 1909-10.

Cinders (Average of 6 Samples)	Percentage by Weight.
Moisture	14·1
Combustible (including Volatile) ...	22·0
Ash	63·9
Total	100·0
Calorific Value B.Th.U. per lb.	1,815

Dayton 1909-10

Cinders (Average of 9 Samples)	Percentage by Weight.
Moisture	19·3
Combustible (including Volatile) ...	21·5
Ash	59·2
Total	100·0
Calorific Value B.Th.U. per lb.	2,517

Later analysis taken by Bureau of Soils, U.S. Department of Agriculture, in 1916 show for Washington results very similar to those we obtained at Falkirk.

Cinders (Average of 45 Samples)	Percentage by Weight.
Moisture	2.1
Combustible (including Volatile) ...	52.6
Ash	45.3
Total	100·0
Calorific Value B.Th.U. per lb.	7,932

European results for unscreened show that there is a general uniformity of Calorific Value with a mean somewhere around the figure of 3500 B.Th.U.

The "Zeitschrift", Oester, Ing. und Arch - Verein, No.35 of 1906 Page 497 gives:-

Town.		Calorific Value.
Barmen	...	4050
Beuthen, Silesia,	...	8050
Dortmund	...	4140
Frankfurt am Mein	...	4086
Miskolez, Hungary	...	2880
Vienna	...	2943
Wiesbaden	...	4140

From "Elektrotechnische Zeit", Heft 26 of 1907, on page 642.

Town.		Calorific Value.
Berlin, Summer	...	1890
Charlottenburg, Summer		1980
" Winter		1800
Mainz	...	3780

From "Die Stadt", Verbrenningsanstalt, L.Boto, 1907 on page 8.

Town.		Calorific Value.
Kiel	...	3240

From Zeit. Ing. No.40, 1907 on page 665.

Town.		Calorific Value.
Pforzheim	...	3600

It will be seen from these figures that the heat value is concentrated in the sizes removed by screening.

In 1919 an Electricity Commission was formed under the Board of Trade to control and centralise Electricity Generating Stations throughout the country, the main object being the conservation of coal and the elimination of all uneconomical plants.

This was ample justification for the reclamation of burnable cinder which would otherwise be lost. In Falkirk the annual amount of refuse dealt with was approximately 9000 tons for a population of 34,000 and from this approximately 3330 tons of burnable Cinder was converted into Electricity.

Mr.Climie, the Electricity Manager, carried out some interesting tests to show justification for the use of the reclaimed fuel and for the year 1923-1924 gave the following return:-

Total fuel used	6824 tons.
Cinders screened from Town Refuse	2500 "
Total cost of fuel	£4642
Units of Current generated ...	4,689,330
Cost of fuel per unit generated	·23d.

This last item included all cartages of coal and disposal of ashes and compared favourably with much larger Stations in the Country where nothing but screwed and washed coal was consumed.

Several Boiler Tests were carried out using both the mixture and the Cinder alone and the following results from three such tests at different times can be taken as a fair representation of the value of this recovered Fuel.

Evaporation Tests /

Evaporation Tests.

	No.1. 50/50 Mixture Cinder & Gum.	No.2. Cinder only	No.3. 50/50 Mixture Cinder & Gum.
(1) Date of Test	20/3/25	12/5/26	17/5/26
(2) Duration of Test in hours	9	9	18
(3) Weight of Fuel Fired in lbs.	32,030	35,184	44,800
(4) Weight of Water Evaporated, lbs.	173,800	137,200	206,800
(5) Average Steam Pressure lbs./	170	175	175
(6) Average Superheat at Temperature ^{O}F	550	560	575
(7) Average Feed Temperature ^{O}F	114	108	110
(8) Factor of Evaporation	1.34	1.34	1.36
(9) Equivalent Evaporation from and at $212^{O}F$ in lbs.	232,892	183,848	281,248
(10) Boiler Efficiency per cent.	77·9	63.5	67.4
(11) Calorific Value of Fuel in B.Th.U.	9,000	8,000	9,000
(12) Total B.Th.U. content in fuel used	288,270,000	281,472,000	403,200,000
(13) Actual Evaporation per lb. of Fuel	5.42	3.9	4.61
(14) Equivalent Evaporation from and at 212oF.	7.26	5.22	6.26
(15) Cost per Ton.	7/9	5/-	7/7
(16) Cost of Evaporating 1000 lbs.of water from and at $212^{O}F$.	6.2d.	7.6d.	7.2d.
(17) Lbs.of Fuel per unit Generated	2.82	3.73	3·06
(18) Lbs.of Water per unit Generated	15.31	14.56	15·07
(19) Units Generated	11,350	9,420	13,720
(20) Average CO_2 per cent.	11	8	12
(21) Capacity of Plant in K.W.	3,000	1,500	1,500
(22) Plant Load Factor per cent.	46·6	69	50
(23) Average Load in K.W.	1,260	1,047	760
(24) Cost in pence per unit generated	·115	·098	·125

In the Greenock Destructor Plant steam was generated in three boilers of the Babcock & Wilcox marine type fired by crude refuse consisting of ashes, rubbish and manure. About 57 tons being burnt daily

The destructor was of the Horsfall "tub fed" type with six cells. The boilers worked at 200 lbs.per square inch and had superheaters; the final heat of the steam being 550° F.

During 1909 an average of 67·2 K.W. hour per ton of refuse burned was obtained and if this is compared it will be seen that by separating the cinder the Falkirk scheme shows an improvement of 7·8 K.W. hour per ton.

It is, of course, only very approximate comparisons that can be made between results in different towns, or even results from refuse collected from different parts of the same town as the mixture is so very variable; but by comparing results obtained from towns in various quarters of the world there is a surprising closeness of comparable results which shows that if used with discrimination figures from other sources are not without value.

(3) Tins.

Scrap tins by weight amounted to less than 1% of the total, actually $\frac{3}{4}$% was a usual average and on account of the small tonage coming in it was not considered economic to instal a baler.

The material in bulk was easily disposed of a few years ago, there being a steady demand at 27/6d. per ton F.O.R., while prices averaging 45/- per ton were common for baled tins.

The present low price of scrap steel makes even baled tins practically unsaleable, so great difficulty may be anticipated in getting rid of unbaled tins which are extremely bulky. Scrap tins sell as mild steel scrap. The actual "tin" which, along with 60% to 80% lead, forms the extremely thin protective coating is so negligible in quantity that it is not now considered economic to salve although, prior to the war, when the tin coating was much thicker there was a considerable amount of salving of tin done in Germany.

Steel foundry managers look on baled tins as the poorest form of M.S. scrap as the high oxygen content tends to unbalance the furnace charge and the melting loss is very considerable.

It can be taken as established that even baled tins are almost unsaleable during years of plenty, or if saleable, the return will do little more than cover the cost of railing.

(4) <u>Scrap Metal</u>.

This amounts only to .32% of the collection and is worth sorting out and selling. Malleable, at the time figures were taken, was fetching 27/6d. per ton F.O.R. and cast scrap was purchased by local ironmongers for a much as £3 per ton. These prices have steadily retarded but scrap metal can always be disposed of and at the worst it is always worth taking away.

(5) Rags.

These account for ·43% and are picked by girls from the travelling belt table. They are sorted in 3 grades:-

(a) Bagging.

(b) Cottons.

(c) Woollens.

(a) and (b) have been disposed of at £1 per ton and (c) at a figure, sometimes as high as £14 per ton.

(6) Bones.

These amount to only ·1% but they are well worth salving as they are valuable for the production of bone-black glue and their manurial value is high on account of the 33% Phosphates and 3% Nitrogen which they contain.

(7) Cullet.

This when clear has been disposed of at as much as 10/- per ton but is now practically unsaleable, especially the coloured varieties.

In Edinburgh at the present time it is very difficult to get any taken away as the amount required by local glass works is very small.

(8) Paper.

This was picked and hand baled and although it was not expected that any considerable revenue would result it fetched an average price of 9/6d. per ton.

The paper amounted to $1\frac{1}{2}\%$ of the collection but it is very bulky and was responsible for a great deal of bad separation in the riddle as it carried dust and sometimes cinders through on to the picking band.

(9) Tailings.

The obvious method of disposing of the tailings in a plant of this description was by incineration and this is what was eventually done but before this, tests were carried out by the local Gas Engineer and Manager, Mr. Ritchie, with a view to ascertaining the value of this residue as a gas producing material.

An experimental, one-hundredth part of a ton, coal gas plant was used. This consisted of a cast iron retort which was externally heated by a gas coke furnace, the gas passing through a water cooled condenser to a coke-filled scrubber for extraction of ammonia and an oxide of iron purifier.

Test No.1.

Gas per ton of Material in cubic feet	6,252
B.Th.U. per cub. foot of gas	204
B.Th.U. per ton of Tailings	1,275,308
Therms " " " "	12.75

Test No.2.

Gas per ton of material in cubit feet	10,720
B.Th.U. per cub. foot of gas	305
B.Th.U. per ton of tailings	3,269,000
Therms " " " "	32·69

It was not possible to make a complete gas analysis but with the Orsat apparatus the following results were obtained from a sample taken from No.1 Test

CO_2	...	...	15·9 %
O	...	...	·8 %
CO	...	...	13·3 %

A valuable comparison with the above is obtained from an examination of the results obtained in a low temperature producer plant erected at Burnley in 1930 by The Whitfield Gas Producers Ltd.

The failure in the past of using gas producers for dealing with town refuse was due to the difficulty of uniform air distribution through the combustion zone. The variant character of the fuel allowed reduced air resistance at points to cause excessive combustion so that "chimneys" were formed through the fuel bed localising the heat and causing the formation of clinkers which were difficult to remove. The "chimneys" formed caused further lowering in efficiency through the admittance of air which combined in the producer to lower the CO content and raise the CO_2; further, the heat produced raised the temperature of the gas and the excessive cooling required resulted in thermal losses, also tar troubles owing to the larger amount entrained in the gas leaving the producer at excessive temperature.

The Whitefield process was designed to overcome these difficulties by an arrangement whereby the air supply was restricted uniformly over the whole grate area irrespective of the fuel bed above and a revolving water cooled scraper freed the clinker which dropped into a quenching pan.

Some success would appear to have been made at Burnley where the whole input, with the exception of bulky articles such as mattresses or carcases which require high temperature incineration, was dealt with. The results obtained are interesting for comparison with those taken experimentally with tailings only, at Falkirk.

Test Results of Producer Gas From Burnley.

Test No.1.

With 4'9" dia. Producer.

Gas per ton of Refuse burnt in cub. ft.		= 6,430
B.Th.U. per cubic foot	...	= 117.4

Test No.2.

With 8'0" dia. Producer.

Gas per ton of Refuse burnt, in cub.ft.		= 5,520
B.Th.U. per cubic foot	...	= 132

An analysis of the Burnley gas showed:-

Carbon Dioxide	...	10·2 % by volume.
Oxygen	...	·4 % " "
Nitrogen	...	48·2 % " "
Carbon Monoxide and Hydrogen		40 % " "
Hydro Carbons	...	1·2 % " "
	Total	100

The Falkirk proposal to utilise the tailings only for gas production would appear in some respects a more economic proposition as, obviously, an incinerator must also be provided if it is desired to reduce all the input in one plant, otherwise a very considerable amount will remain for railing to the country dump.

A very significant point in regard to the plant operating at Burnley was the clinker content which approached 50% of the refuse fed to the producer so a considerable amount of material had to be removed although it was of a completely changed character and unlikely to cause nuisance of any description when dumped.

I believe Cleansing Inspectors are agreed that a good deal of experimental work is still required before the commercial possibilities of gas production from the tailings of screened refuse are established and, up to the present time, the simplest, most satisfactory and most economical method is undoubtedly by incineration.

The process which was embodied in the plant operating in Falkirk is of special interest in view of the low current cost shown by the power station when, in 1932, the Electricity Board endeavoured to make terms with a view to their joining the Grid scheme.

It must be borne in mind that this Falkirk plant was really a pioneer plant introducing a new idea into Scotland and the results obtained were closely watched by other municipalities. The next plant in which I was personally interested was for the Edinburgh Corporation and its erection may be considered as a direct result of the successful work done in Falkirk although the aim was quite different.

In Edinburgh no attempt was made to dispose of the cinder content of the domestic refuse as a fuel. The aim there being to reclaim waste and useless ground by the dumping of prepared refuse and so increase the land value that it will, in time, show a capital appreciation representing the revenue obtained from the refuse.

This was first tried out on a small scale in the village of Blackhall and here for the first time the jigging conveyor type of separating machine was used.

I had for some time felt that there was a more satisfactory means of separating refuse than the riddle which, although fairly efficient, had proved expensive in first cost, very clumsy and extremely inaccessible when screens required renewing.

Suggestions were made that jigging machines or zimmers as used for coal separation might be used but neither of these appeared satisfactory from every point of view.

It was about this time that the introduction of a portable jigging conveyor for underground work at a colliery had, to a great extent, revolutionised coal handling below ground and a modified combination of this and the "Marcus" separating table appeared to be a possible solution.

I took a deputation of members of the Town Council of Edinburgh along with Mr.Macrae, the City Architect, to see a "Marcus" table in operation at a Colliery near Glasgow and was able to convince them that the machine proposed had destinct possibilities.

It was then agreed that a machine of the type suggested should be incorporated in this experimental plant so that its efficiency might be tested as a possible solution for the development of a larger plant in the city.

The scheme at Blackhall was one which had not previously been tried in Scotland. In the centre of the village, behind the houses was situated a disused quarry full of stagnant water. It was proposed to erect the plant on a site adjacent to the quarry hole and fill this up, so reclaiming a piece of otherwise useless ground.

The proximity to dwelling houses made it imperative that no nuisance should emanate from the plant and in the years following its erection until the ground was re-claimed the only finger which could be pointed against this little plant was on this score.

The input was designed at 20 tons per diem although this was often increased to 25 and it is unfortunate that no record remains of the exact working during its lifetime as no weighbridge was incorporated in the scheme.

This plant proved quite definitely the superiority of the jigging table type of separating machine for domestic refuse and in consequence this machine was incorporated later in the specifications for further plant.

The method employed at Blackhall was to back the refuse trailer on to a flat tipping plate from which refuse was pushed by hand on to the end of the jigging table.

This table was similar to that shown in Plate 9 except that a step was introduced about half way along the top perforations. This was 4 inches deep and was intended to turn over articles travelling along the top plate and so aid the separation. It was found unnecessary and was not again incorporated.

The throw of this table was about 10 inches and the method adopted of polishing the top perforations and the bottom plain plate was to load the machine with bricks and blind the outlet end. The machine was run under these conditions until the necessary well polished surface was obtained.

Tins and glass were hand picked during separation. The tins being baled in a small power driven baler which compressed a load into a cube about 1 foot and about 80 lb. weight. The glass was removed to save the fire-bars in the tailings incinerator which was hand fed and was situated at the end of the separating table.

The separated material after passing an $1\frac{1}{2}$ inch hole fell on to the plain plate on the bottom of the machine and was conveyed to a point where it was discharged into the boot of an elevator and raised to feed into a storage hopper from which the material was loaded into skips on a light track and discharged into the quarry hole.

It will be seen that the only material used for making up-ground, apart from clinker removed from the furnace, was refuse which had passed through an $1\frac{1}{2}$ inch hole and on account of this the made up-ground became rapidly firm and hard and was in every way superior to ground reclaimed by the tipping of crude refuse.

The incinerator dealt most effectively with the tailings but considerable trouble arose owing to emissions from the 30 foot brick lined steel chimney. It was very difficult to prevent paper from issuing from the stack and floating away still in flames, and complaints from adjacent houses became so numerous, towards the end, that it is doubtful whether, had the quarry been larger, the continued operation of the plant would have been allowed.

Various grids at the top of the chimney were tried out but none were successful, which is not surprising when one considers the temperature they were subjected to.

The last grid was made from a type of Hadfield steel which was on view at the time at the Newcastle Exhibition. This steel had a melting point approaching 4000°F. but unfortunately its tensile strength was lowered to a point at which it was unable to support its own weight when subjected to a chimney temperature of about one quarter of that amount, so that it sagged down from the top until it had to be removed.

This Blackhall plant was erected as an experiment to explore the possibilities of making up ground in residential areas by the dumping of prepared refuse. The actual depth made up was slightly over thirty feet and a costly mistake was made in the original arrangement by making up to the top level from the commencement. The weight of some thirty feet of new refuse was sufficient to increase the heat generated by the decomposition of the vegetable content to a point where spontaneous combustion took place and the fire thus started took several weeks to put out and in the process necessitated the expenditure of a considerable sum of money.

The fire and its direction of travel was located by sinking in the ground, from which the only indications of fire were wisps of smoke rising from several points, a series of tubes of the type used in electric light installation work. These tubes allowed thermometers on strings to be suspended at various heights and positions and by systematic readings the position of the actual heart of the fire was established.

The top layer immediately above the heart of the fire was removed to as low a level as possible before the heat and fumes drove men from the spot and water from a portable pumping plant was arranged to flood over this spot in considerable quantities day and night until the thermometer readings from the surrounding ground showed that all trace of excessive heat had disappeared.

It is now established that at a depth of thirty feet combustion is practically certain to take place and a solution to the problem was obtained by filling to about twelve feet over the whole area, this took several years and when completed the refuse at the point from which filling commenced was absolutely inert and would safely bear the load of the remaining height of fresh refuse on the top of it.

The filling was carried out by laying a light track along the made up ground and using side tipping skips filled by a chute from the storage hopper at the plant.

The success of the Blackhall experiment resulted in the erection along very similar lines of the 100 ton plant still in operation at Powerhall.

This plant was designed in 1928 and completed in 1929 and on account of its mechanical efficiency and the simplicity of its aim the results obtained have amply fulfilled the expectations of those responsible for its conception.

The site was chosen on account of several important features

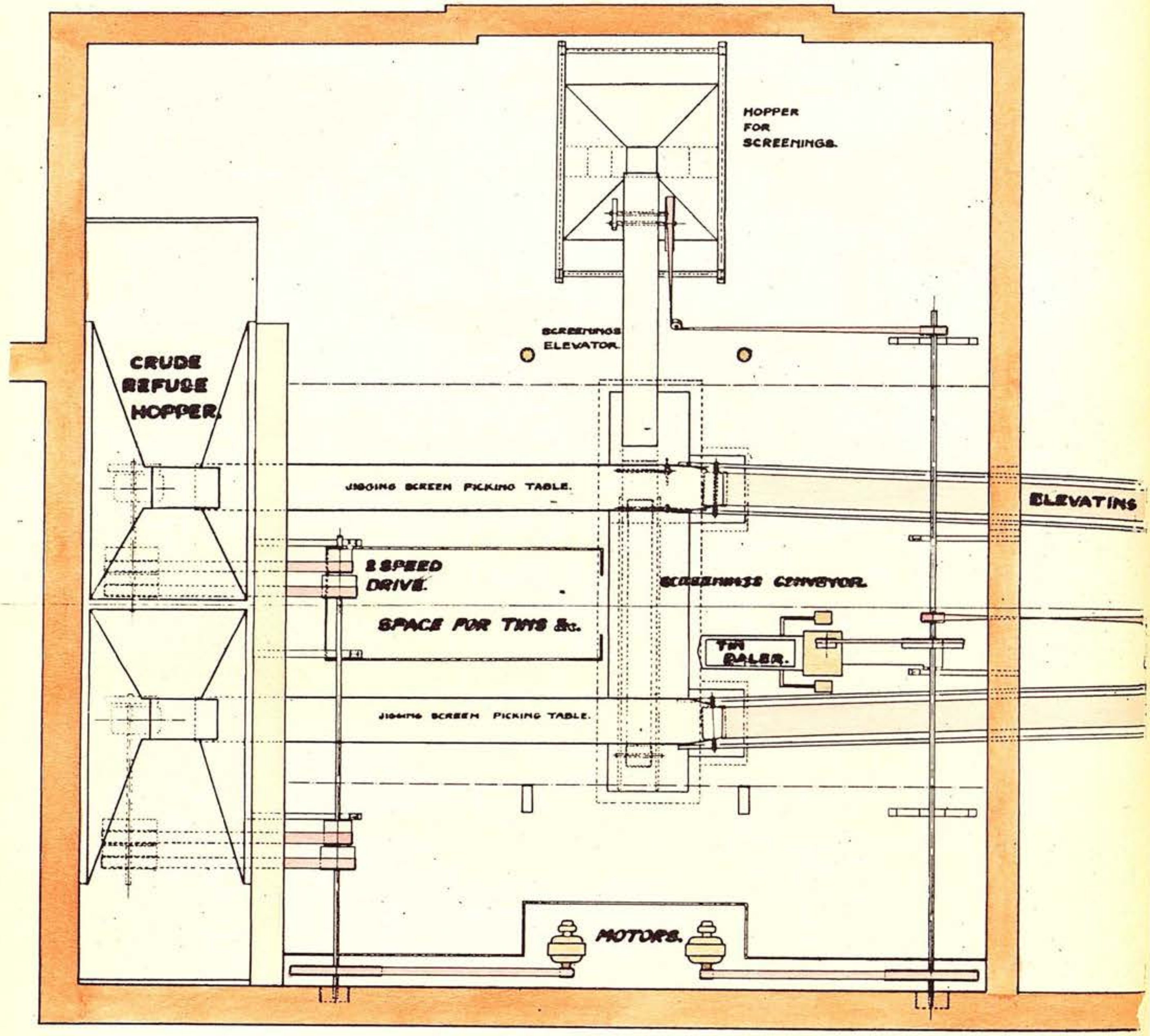
(a) It was centrally placed for collection from a large area.

(b) It had old buildings dating from the time an attempt had been made to form a central incinerator and these were utilised to house the machinery.

(c) There was closely adjoining ground to be made up to a level of twelve to fifteen feet which would take the output of the plant for at least fifteen years.

(d) There was suitably positioned on the ground a large chimney stack in good repair.

The plant was designed for an input of 100 tons per 8 hour day and its capacity for overload can be judged from


HOPPER
FOR
SCREENINGS.
SCREENINGS
ELEVATOR.
CRUDE
REFUSE
HOPPER.
JIGGING SCREEN PICKING TABLE.
ELEVATING
2 SPEED
DRIVE.
SPACE FOR TINS &c.
TIN
BALER.
JIGGING SCREEN PICKING TABLE.
MOTORS.

PLAN.

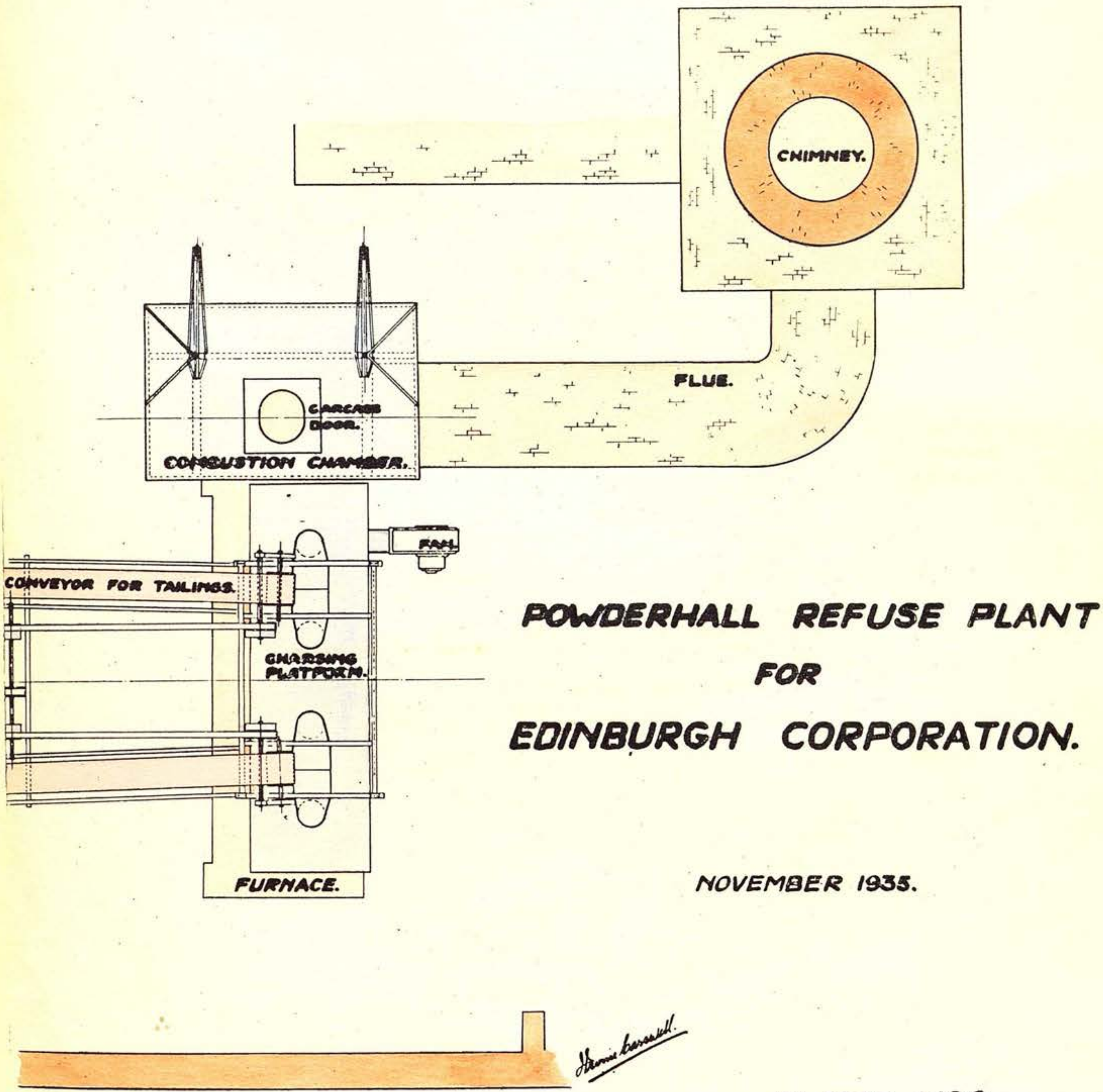

CHIMNEY.
FLUE.
CARCASS DOOR.
COMBUSTION CHAMBER.
FAN.
CONVEYOR FOR TAILINGS.
CHARGING PLATFORM.
FURNACE.
POWDERHALL REFUSE PLANT
FOR
EDINBURGH CORPORATION.
NOVEMBER 1935.

PLATE Nº8.

POWDERHALL TOWN REFUSE PLANT.

Results from November 13th to December 13th, 1931.

	Total Input.		Screenings.		Tins.		Clinker.		Current.	Furnace	
Date.	Tons.	Cwts.	Tons.	Cwts.	Tons.	Cwts.	Tons.	Cwts.	Units.	Tons.	Cwts.
Nov.											
13th	154	14	96	18	1	17	7	16	184	51	19
14th) Sat.)	124	0	80	10	1	8	9	2	140	33	6
16th	164	16	117	16	2	5	9	16	218	44	13
17th	134	0	89	6	1	11	9	2	179	39	7
18th	118	9	76	18	1	9	9	2	161	39	12
19th	141	4	98	16	1	12	8	16	168	40	16
20th	159	11	102	12	1	17	10	2	184	55	12
21st) Sat.)	150	10	102	12	1	13	11	14	163	46	5
23rd	163	7	117	10	2	5	10	2	192	43	6
24th	138	4	95	8	1	12	9	2	167	41	4
25th	141	0	101	16	1	12	8	16	175	36	13
26th	126	8	89	6	1	9	7	16	143	35	13
27th	153	12	104	10	1	18	10	2	184	47	4
28th) Sat.)	144	5	98	16	1	13	10	8	171	43	16
30th	157	12	114	11	2	2	11	2	205	41	9
Dec.											
1st	134	17	99	19	1	12	9	2	173	33	6
2nd	137	7	101	2	1	13	7	16	175	34	12
3rd	116	3	77	18	1	2	7	16	158	37	3
4th	177	3	125	8	2	2	10	12	211	49	13
5th) Sat.)	154	8	102	12	1	9	10	8	188	57	0
7th	172	6	118	8	Break-down of Baler.	11	11	2	215	53	7
8th	135	6	101	7	1	14	9	2	184	33	5
9th	135	5	97	9	1	10	9	2	194	36	6
10th	127	11	89	6	1	9	7	16	178	36	16
11th	157	16	111	3	1	18	9	16	197	44	15
12th) Sat.)	136	16	91	4	1	17	10	2	178	43	15

Results for April 1932.

	Total Input.		Screenings.		Tins.		Clinker.		Current.	Furnace.	
Date.	Tons.	Cwts.	Tons.	Cwts.	Tons.	Cwts.	Tons.	Cwts.	Units.	Tons.	Cwts.
1st	146	2	90	2	1	19	9	2	182	54	1
2nd) Sat.)	142	6	95	0	1	12	10	8	297	45	14
4th	159	8	111	4	1	19	11	8	170	56	15
5th	141	9	102	12	1	12	9	2	169	37	5
6th	124	8	76	0	1	9	10	8	155	47	9
7th	126	19	76	0	1	11	10	2	160	49	8
8th	149	2	99	16	1	18	8	16	185	47	8
9th) Sat.)	123	8	95	0	1	13	10	8	160	26	15
11th	156	0	98	9	1	19	11	8	189	54	12
12th	133	12	85	10	1	12	10	8	168	46	10
13th	127	0	91	4	1	10	10	8	161	34	6
14th	134	15	91	4	1	14	10	8	172	41	17
15th	149	3	113	1	1	17	11	8	184	34	5
16th) Sat.)	147	13	106	8	1	18	11	8	169	39	7
Holiday) 18th) 2 hrs.)	49	3	41	16	0	11	5	4	44	6	16
19th	141	11	106	8	1	19	9	2	186	33	6
20th	132	11	91	10	1	15	10	8	182	39	6
21st	104	13	76	0	1	10	10	2	167	47	3
22nd	144	18	98	18	1	19	9	2	209	41	4
23rd) Sat.)	144	15	91	4	1	11	11	8	167	52	0
25th	157	16	93	5	2	1	12	14	199	62	10
26th	133	5	81	14	1	15	9	2	174	49	16
27th	126	5	79	16	1	9	11	8	174	45	0
28th	119	15	72	4	1	10	10	8	129	46	1
29th	126	11	84	14	1	7	11	8	197	40	10
30th) Sat.)	144	14	87	8	1	16	11	8	177	55	16

WINTER.		SUMMER.	
Average daily Input in tons	144·4	Average daily Input in tons	134·2
" " Screenings in tons	96.23	" " Screenings in tons	89·8
" " Tins in tons	1.653	" " Tins in tons	1.653
" " Clinker in tons	9.43	" " Clinker in tons	10.17
" " Combustible in tons	42.35	" " Combustible in tons	43.2
" " Currents in Units	180·4	" " Current in Units	174·4

Screenings/ton Input	66.75%	Screenings/ton Input	67 %
Tins " "	1·14%	Tins " "	1·23%
Clinker " "	6.53%	Clinker " "	7.8 %
Combustible " "	25.58%	Combustible " "	23.97%

	WINTER.	SUMMER.
Average Current Consumption per ton of Refuse in B.O.T. Units	1·3	1·24
Average Current Consumption/Ton of Refuse	1·272	
Average Screenings/Ton Input	66·85%	
" Tins " "	1·18%	
" Clinker " "	7·04%	
" Combustible " "	24.93%	

CRUDE REFUSE HOPPER.

The storing of crude refuse is always a matter of considerable difficulty as it is not easy to arrange for its removal after it has been in position for any length of time. The hopper erected at Powerhall was designed after many experiments had been made to discover the angle of repose of the average refuse and the angle down which it would feed with reasonable manual assistance from above.

The interior is shown in Plate 13 which is from a photograph taken during construction before the steel framed house protecting the tipping point had been sheeted.

Plates 8, 9, 10 and 11 form a complete set of drawings of the original layout and the hopper shown in Plate 9 and 10 is uncovered as it was not originally intended to house this point.

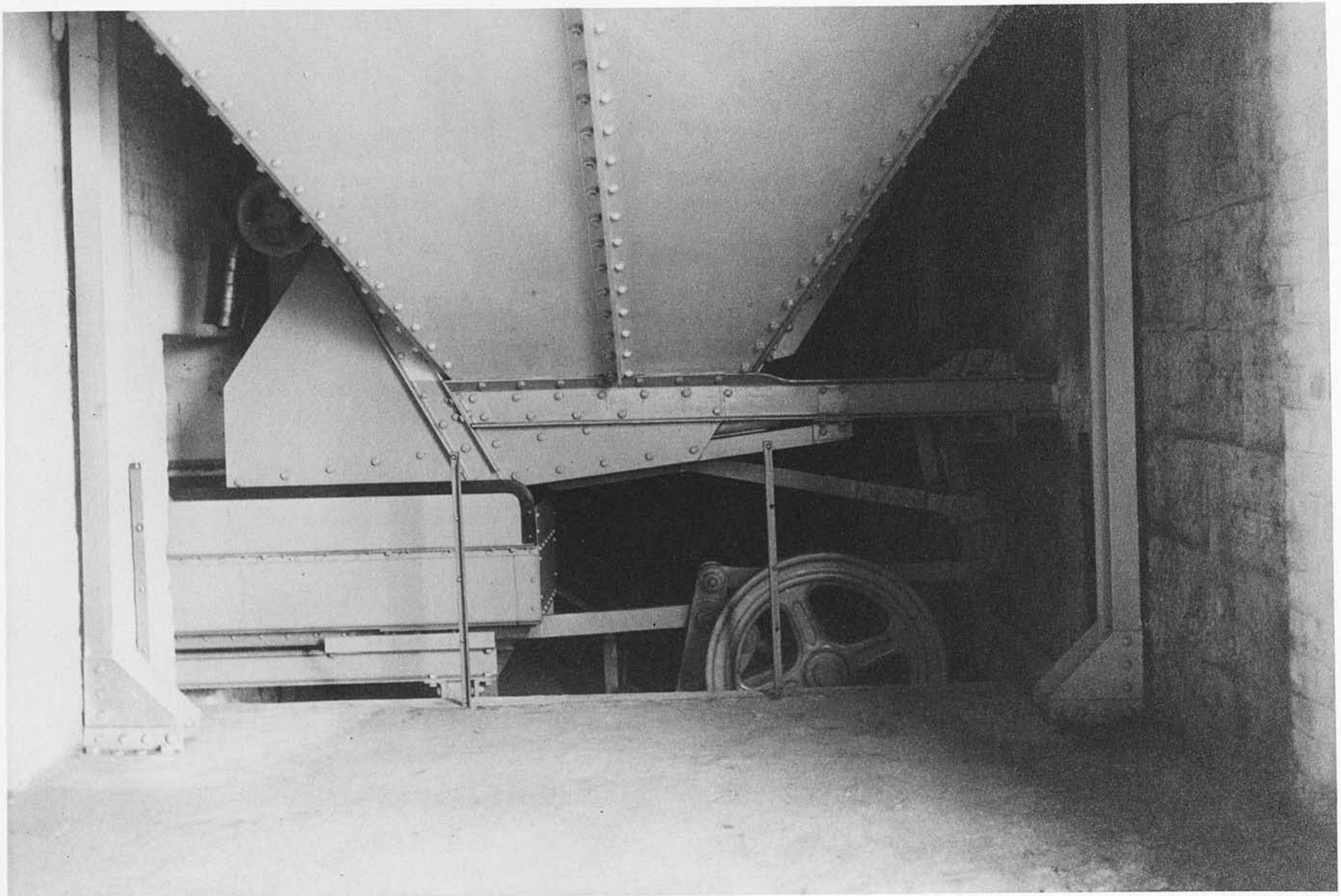
The hopper had a capacity of about 60 tons of crude refuse and the solidity of the design can be judged from the view of the underside in Plate 14 where it will be seen that subsidiary framing to support the Hopper has been dispensed with on account of the great thickness of plate used; these plates were actually $\frac{5}{8}$ inch thick.

The contents of the hopper were fed on to two separate units underneath and stoppages prevented by a

Plate 13.

Cart Tip and Storage Hopper.

Plate 14.



Jigging Screen under Hopper.

man at the tipping point manipulating a long poker made of duralium and so preventing arching underneath.

An effort was made to provide a regular controllable feed on to the picking tables and in Plate 14 the method of feeding first on to a small jigger driven through a linkage from the large machine, will be seen. The linkage used was variable and controlled by a lever in the picking house so that the movement of the small jigger could be regulated from a maximum of 10 inches down to zero.

There was also a sliding vertical door in the opening through which the picking tables protruded through the partition wall so that the height which refuse reached when fed on to the tables could be regulated.

PICKING TABLES.

The picking tables themselves were similar to the one used with success at Blackhall. They were mounted on large balls and had a movement of 10 inches imparted to them by the mechanism shown in Plate 14 which provided a steady forward movement with a quick return. The whole top area of each table was perforated plate with a perforation of $1\frac{1}{2}$ inch holes arranged so that the metal between each two holes was subsequently removed making a screening area which would take articles about $1\frac{1}{2}$ inches by $3\frac{1}{2}$ inches and tended to prevent rags blocking up the holes by partly filling two adjoining ones.

The screenings falling through the perforated plates were carried along to the front of the tables on plain bottom plates and large slots on the sides, see Plate 15, allowed such articles as glass, earthenware etc. which were picked off the top to be fed on to the bottom plate and join the screened refuse on its way to the dump.

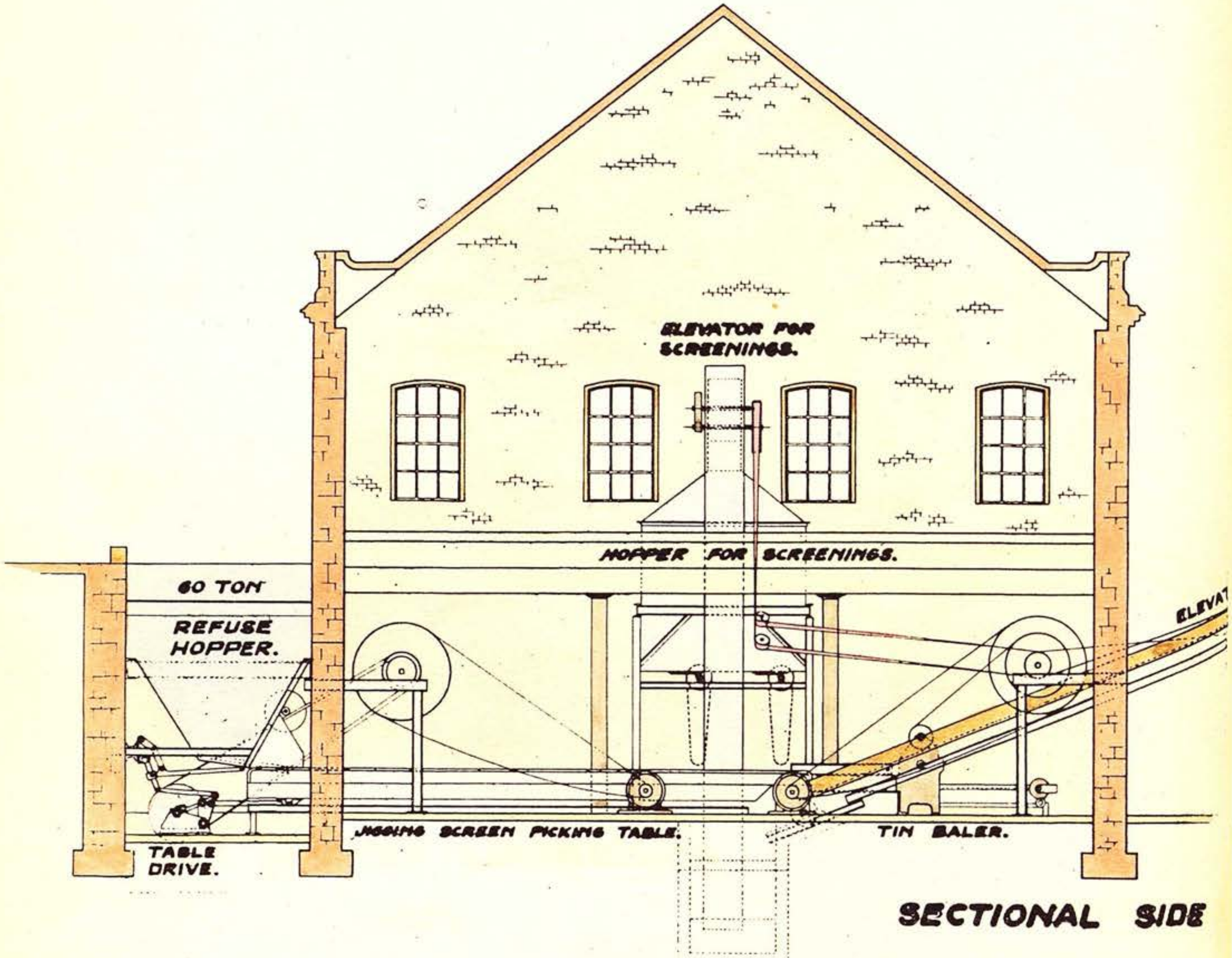
A cross conveyor shown on Plates 8 and 10 conveyed the screenings from one of the tables across the house under floor level to the elevator into which the screenings from the other table dropped directly. These screenings were elevated and discharged into a storage hopper from which they were conveyed by motor to the tipping point on the dump.

The pickers stood on the inside of the tables and salved tins and bones; glass being removed solely to save the furnace fire-bars. The tins were stored in the enclosure shown on Plate 8 and when a sufficient quantity was collected they were baled in the tin baler and stacked outside prior to being sold.

The bones formed a very small percentage of the input and no special provision was required for their storage.

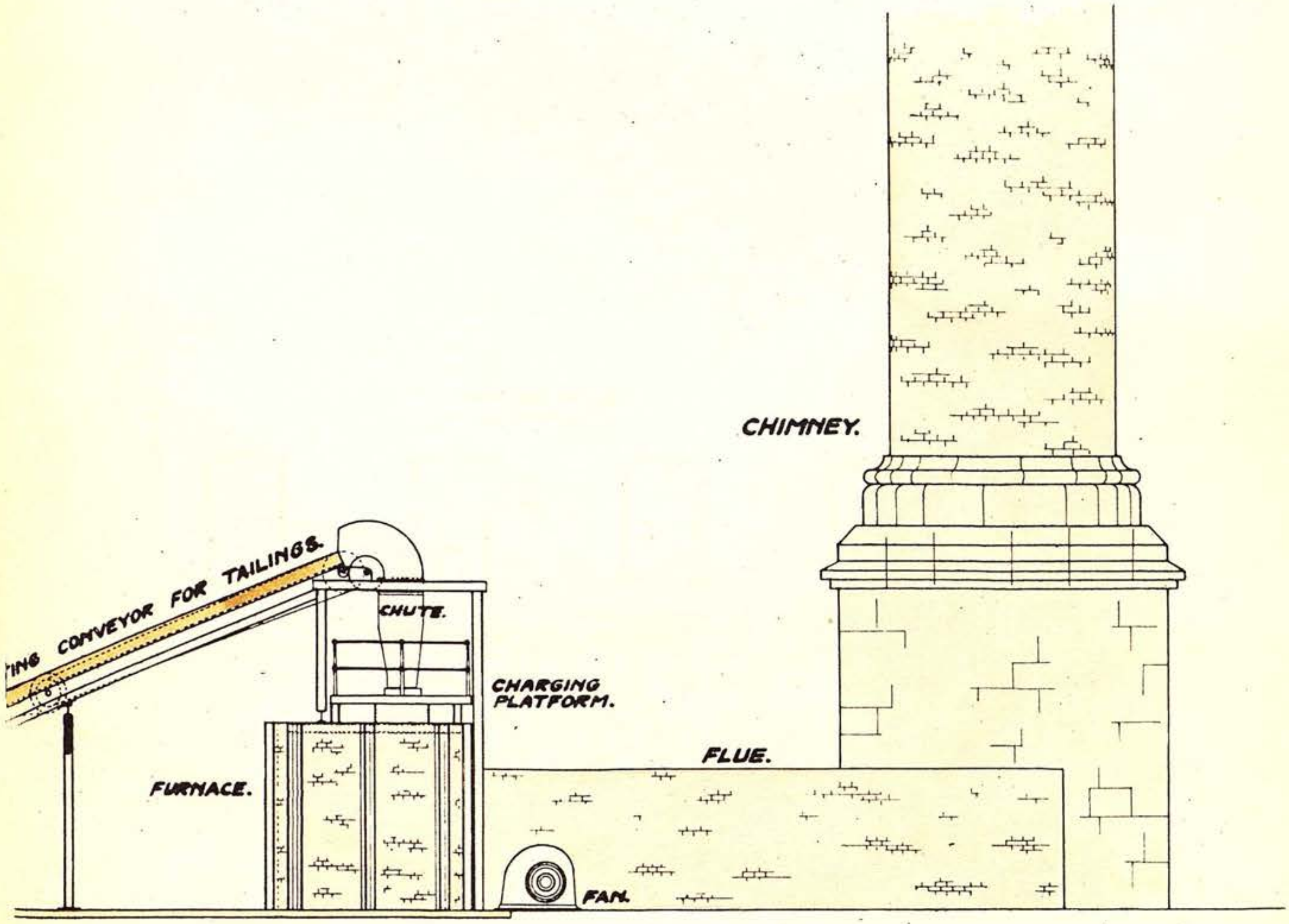
The tailings from both tables were conveyed to the top feed furnace by elevating band conveyors.

ELEVATING BAND CONVEYORS. /



SECTIONAL SIDE

PLATE No 9.



ELEVATION.

POWDERHALL REFUSE PLANT
FOR
EDINBURGH CORPORATION.

DECEMBER 1935.

ELEVATING BAND CONVEYORS.

These were of standard pattern with rubber composition belt running on pulleys as shown in Plates 16 and 18.

It might be anticipated that the belts would deteriorate rapidly due to heat rising at the top end where the tailings were tipped into the furnace, but, although frequently licked by flames at this point, these belts gave excellent service, due, no doubt, to the speed at which they were travelling, taking them out of the hot zone before harm could result.

In the original layout as shown on Plate 9 the conveyors and furnace were exposed, without covering of any description. This proved unsatisfactory and a reproduction from the original drawing dated June 1929 and stamped as approved in July 1929 is shown wherein a steel framed and sheeted housing was provided. This was later extended to ground level with sliding doors on either side of the slab before the furnace doors. The original covering is clearly illustrated in Plate 17.

INCINERATOR.

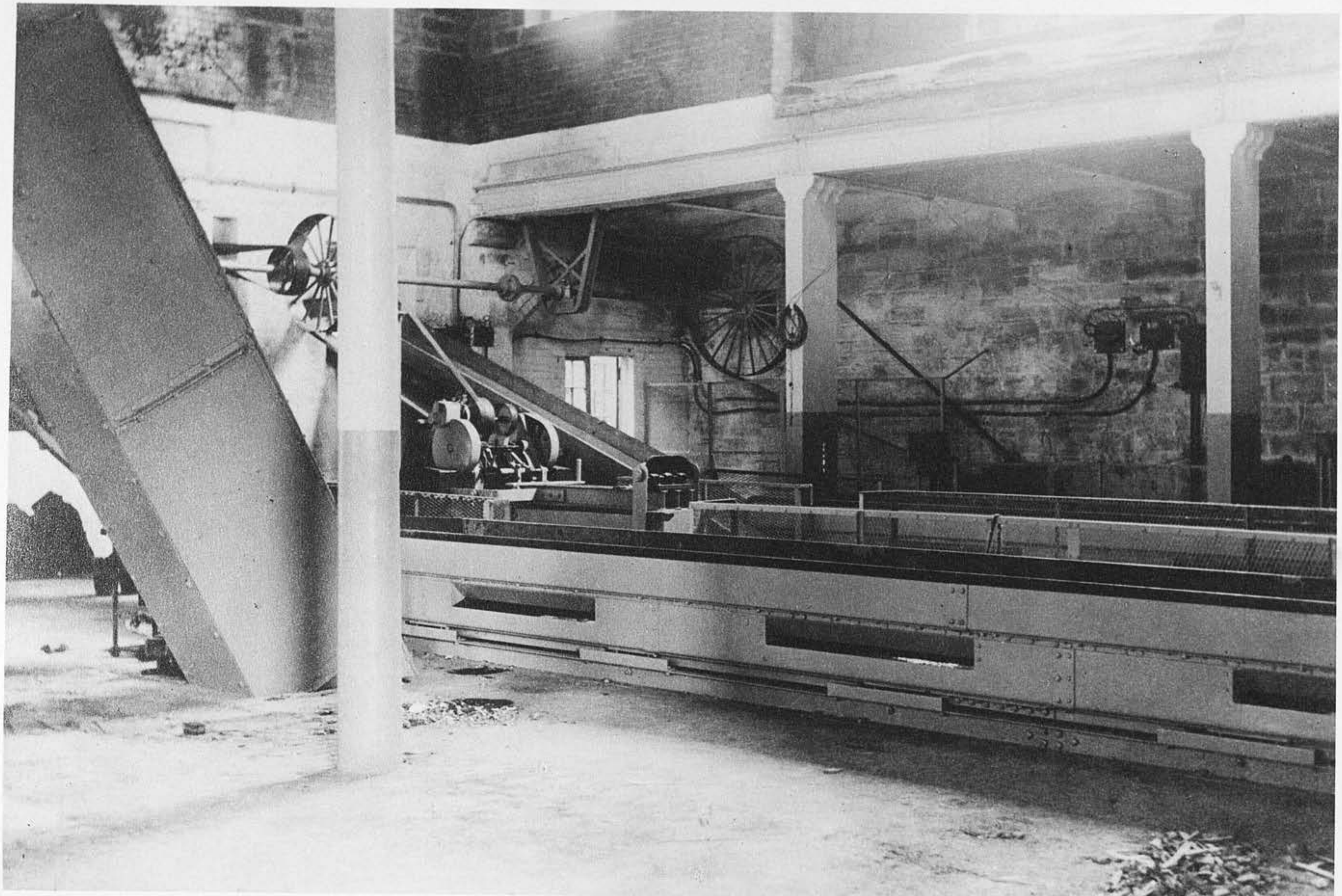
This was known as a 4 cell type top feed furnace. Terminologically this may not be considered correct as the grate bars were continuous from end to end but it was designed to be charged from four different points. Plate 16 shows the four chutes leading to the charging doors situated in the arched roof of the furnace.

It was at one time considered impossible to charge continuously through open top doors when forced draught was used as the gas pressure inside might exceed atmospheric pressure with the resultant exit of flames and the products of combustion out of the open charging doors instead of up the chimney.

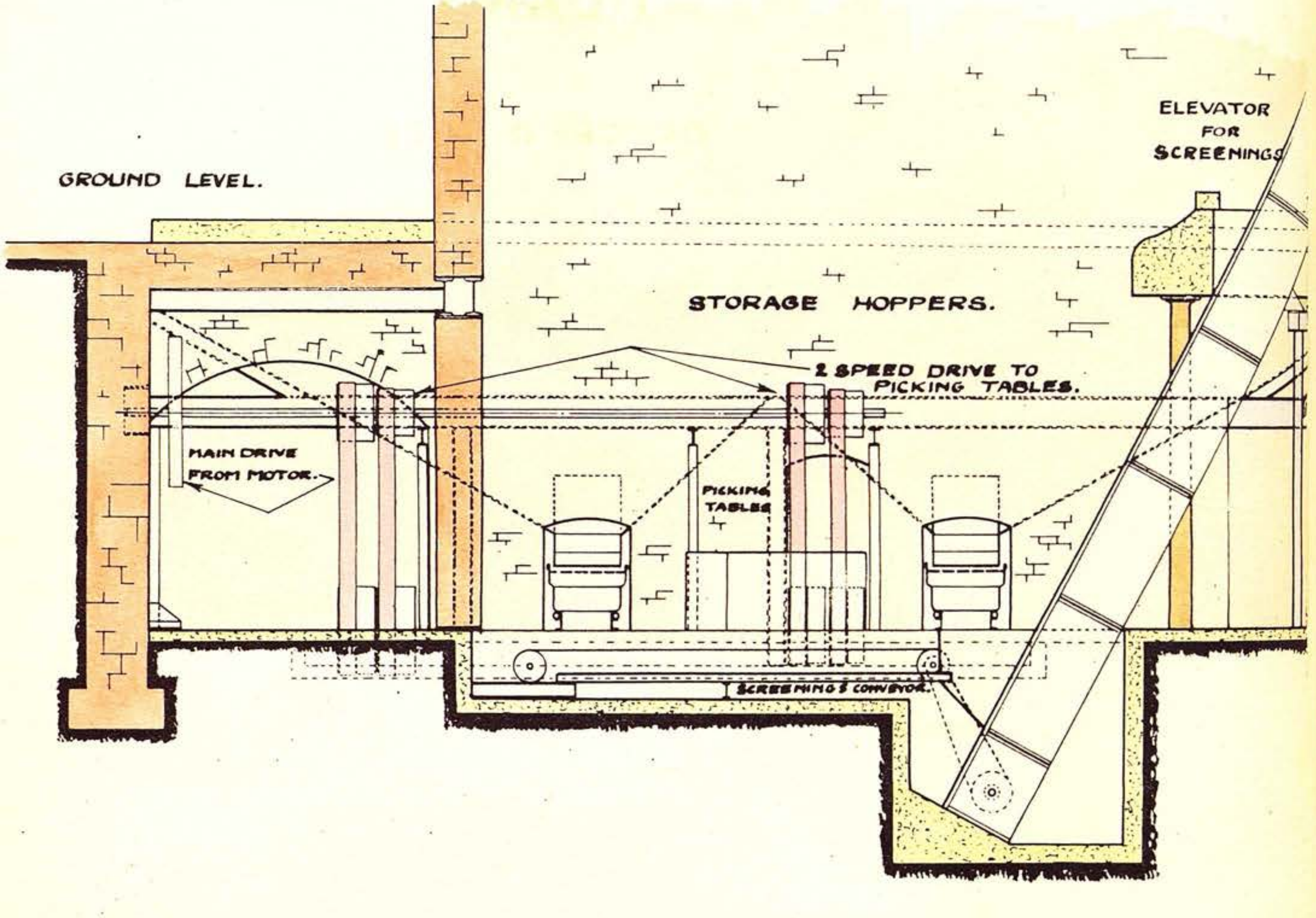
I was asked to join the City Architect and the Cleansing Inspector in a visit to the refuse plant operating in Nottingham and there we saw top feeding being carried out with marked success and with a chimney under 80 feet in height. The chimney available for use at Powerhall was one belonging to a previous incinerator and was 172 feet high so it was felt that top feeding could be safely incorporated in the scheme. In the furnace at Nottingham the top feed was arranged so that the refuse fed in behind the crown arch which was left undisturbed but we considered it necessary for the best results to arrange for the refuse being fed on to the centre of the fire-bars and it was decided to break the centre arching in four places to provide the top feed openings. These openings could be shut from the platform along the top (Plate 16) as each was provided with a horizontal swivelling door composed of a forged steel framing filled with fire-brick.

When these doors were completely open they

Plate 15.



Picking House.

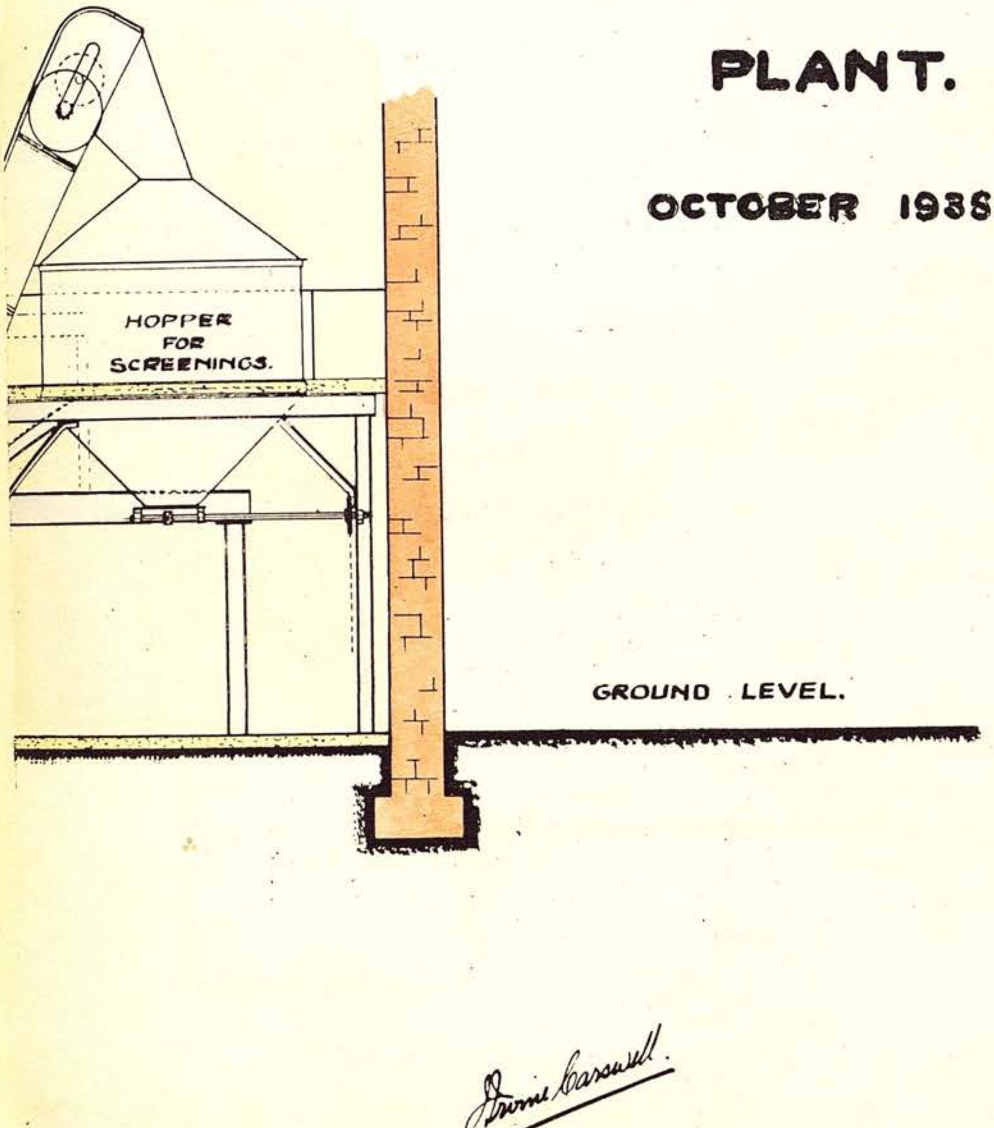


SECTIONAL END ELEVATION

PLATE Nº 10.

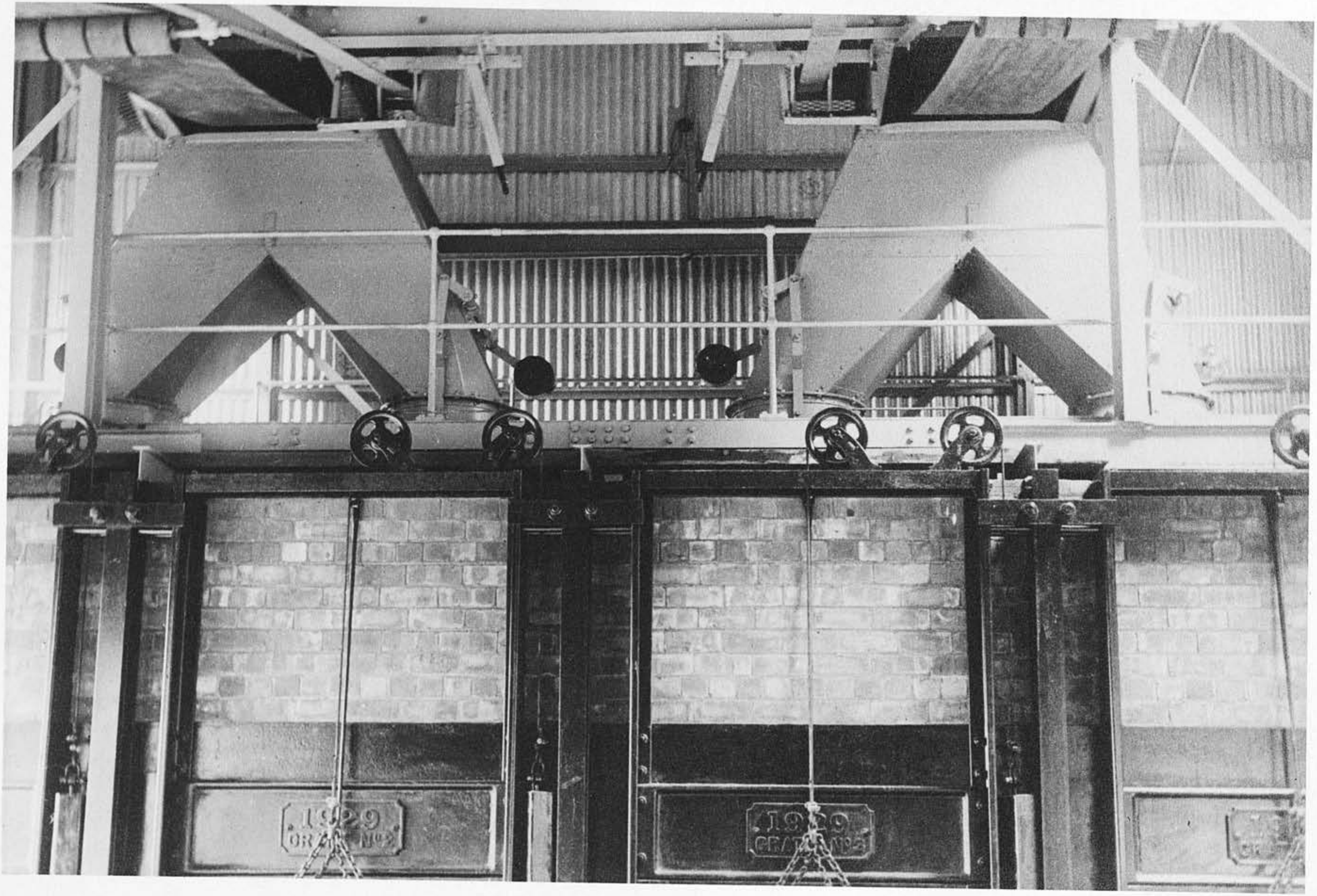
EDINBURGH CORPORATION POWDERHALL DESTRUCTOR PLANT.

OCTOBER 1938.



Jerome Carswell.

Plate 16.



Incinerator.

allowed a steel sleeve on the vertical base of the chute above them to be lowered on to the furnace top and thus close up the opening left by the depth of the door.

The refuse feeding up each conveyor was diverted to one or other of the two cells fed by each chute. This was accomplished by fitting a flap door at the fork where the chutes became one, a weighted arm keeping the door secure in either position.

The Furnace was built of fire-brick in a steel frame and as originally erected a fair amount of "purpose made" bricks were used. These were discarded as much as possible when re-building was required as the "purpose made" brick seemed to have considerably less heat resisting capacity than the standard fire-brick.

The only serious fault which became apparent in the design was the method adopted of joining the flue tunnel to the combustion chamber of the furnace. Plates 8 and 9 show the plan and elevation, the flue having to be brought round an angle of 90° as the chimney was existing and the position of the furnace was fixed by the position of the main shell of the building.

The flue was built on to the back of the combustion chamber without an expansion joint of any kind being incorporated. The result was that when the bricks in the flue expanded with heat they broke joint at the bend where movement took place and this became very badly cracked the maximum movement being about one inch.

It must not be considered necessary to provide a chimney of anything approaching 170 feet in height for normal burning. Kent offers a rational formula based on the theory of Péclet, developed later by Rankine (Ref. "Mechanical Engineers" Pocket Book, 7th Edition, page 732.)

$$H = \frac{P}{\frac{7\cdot64}{Ta} - \frac{7\cdot95}{Tc}}$$

Where 7·64 and 7·95 refer to the densities of the outside air and chimney gases respectively.

H = Height of Chimney in feet.

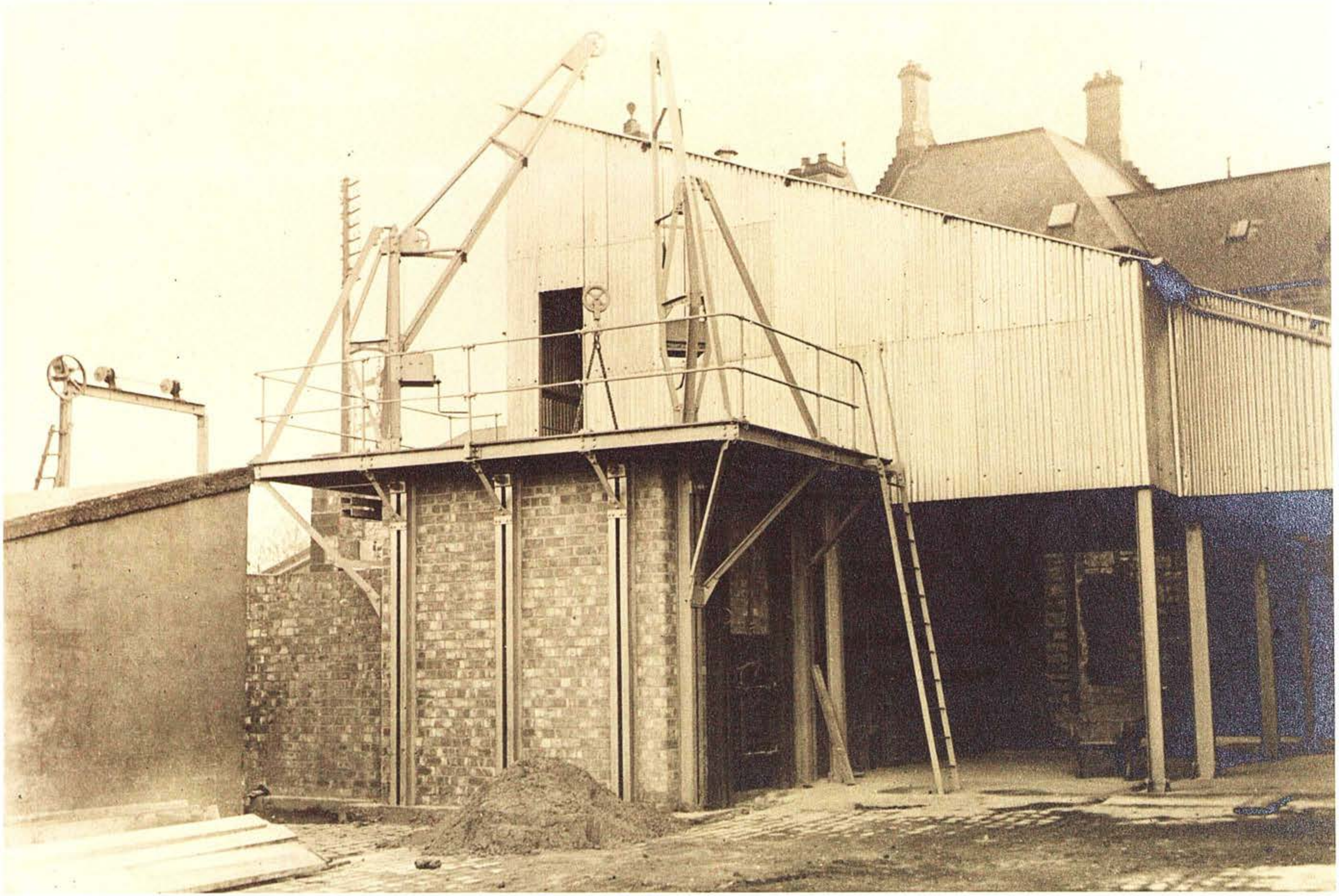
P = Pressure in ashpit in inches of water.

Ta = Absolute temperature of outside air.

Tc = " " of Chimney gases (Average).

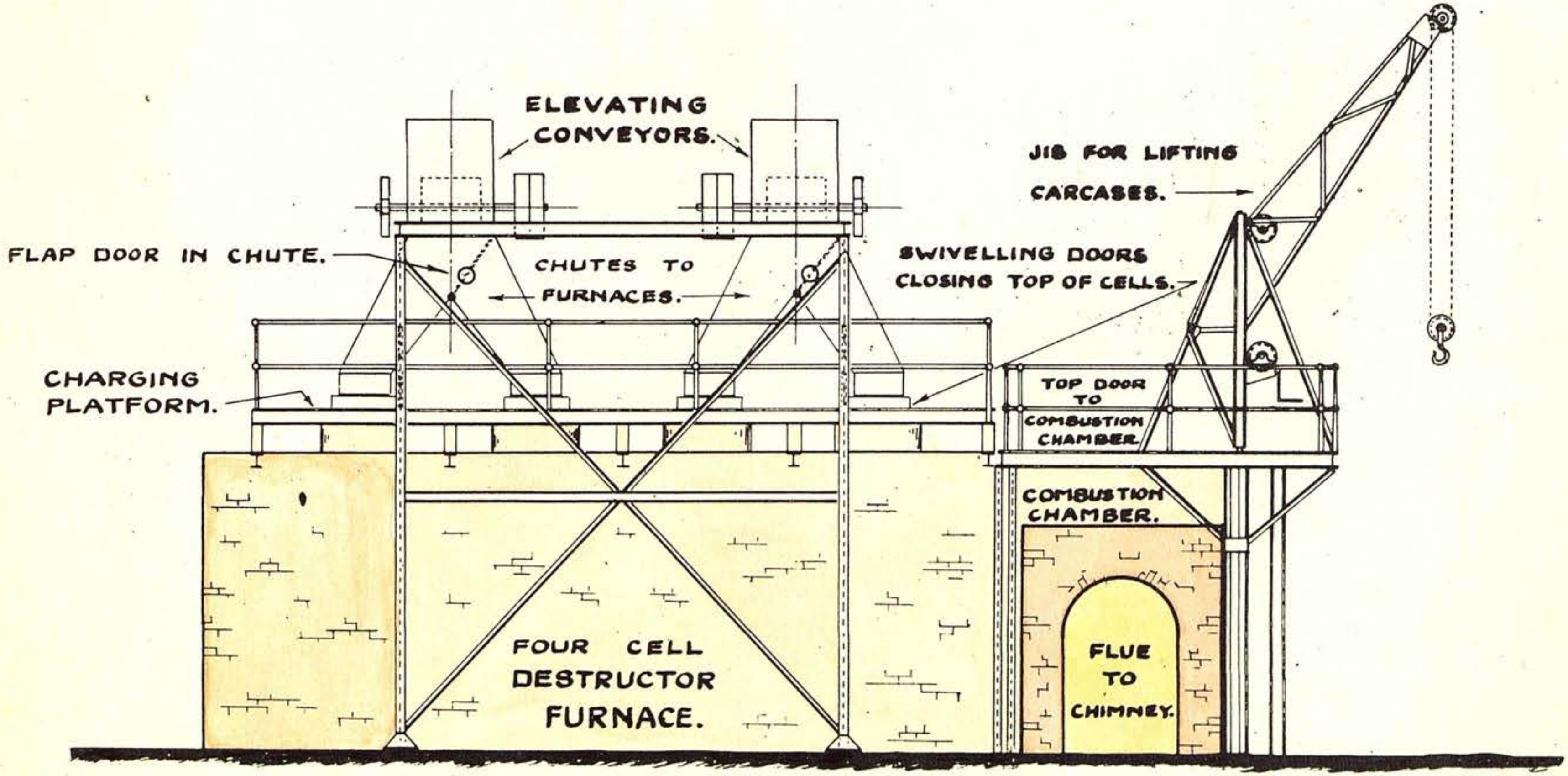
From this it would appear that a height of about 80 feet is sufficient because, if we take normal air temperature at 70°F. with a gas temperature of 600°F. and a pressure below the fire bars of 0·5 of an inch of water, as average values, the height given by the formula would be:-

Plate 17.



Incinerator House.

PLATE No. 11.



END ELEVATION OF POWDERHALL PLANT LOOKING TOWARDS FURNACE.

$$H = \frac{0 \cdot 5}{\frac{7.64}{530} - \frac{7.95}{1060}}$$

$$= 72.5 \text{ feet.}$$

This now appears to be recognised as the necessary and satisfactory chimney height for a furnace of about 50 tons capacity and at Powerhall the exceptional chimney height made it possible to open at least one clinkering door without the combustion pressure becoming higher than atmospheric. This point is extremely important with top feed furnaces as it would be necessary to shut down the blower fan before opening a clinkering door if the above condition did not hold.

The method of refuse incineration where no steam boiler or other method of heat absorption is incorporated in the furnace can only be employed when a sufficient proportion of the high calorific value content of the refuse is removed prior to burning, so that a chimney base temperature below 1000°F. is maintained.

With the top feed furnace, air is admitted at three points:-

(a) Through the feeding chutes.
(b) Through the clinkering doors.
(c) By forced draught through the fire bars.

If combustion is too fierce a certain reduction can be obtained by an excess supply of air, always bearing in mind the necessity of keeping a vacuum of at least half an inch of water at the chimney base.

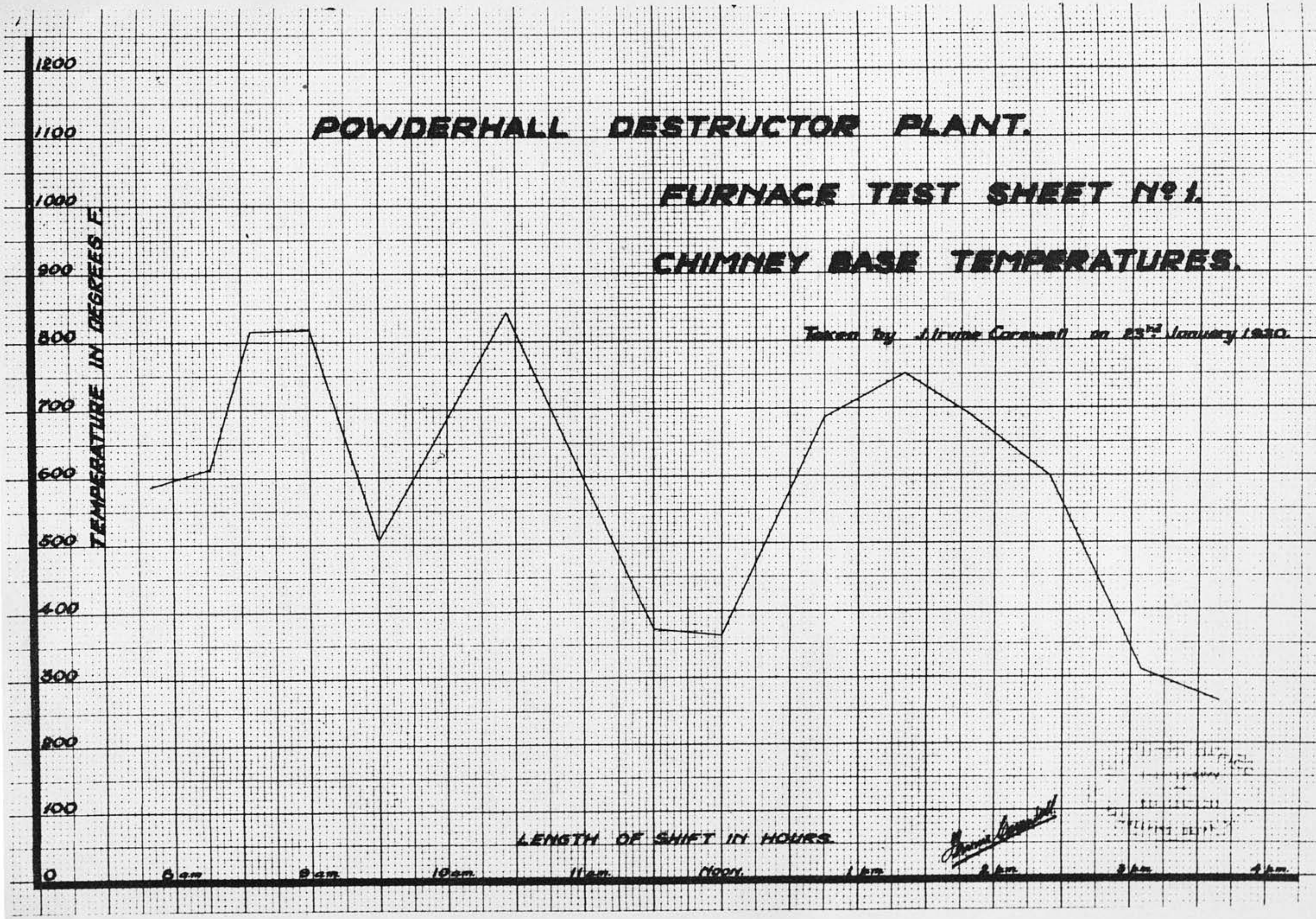
The Dundee Corporation have in use a more recent plant and a great deal of trouble has been experienced there with excess chimney temperatures causing damage to the fire-brick lining and even to the brick casing of the chimney.

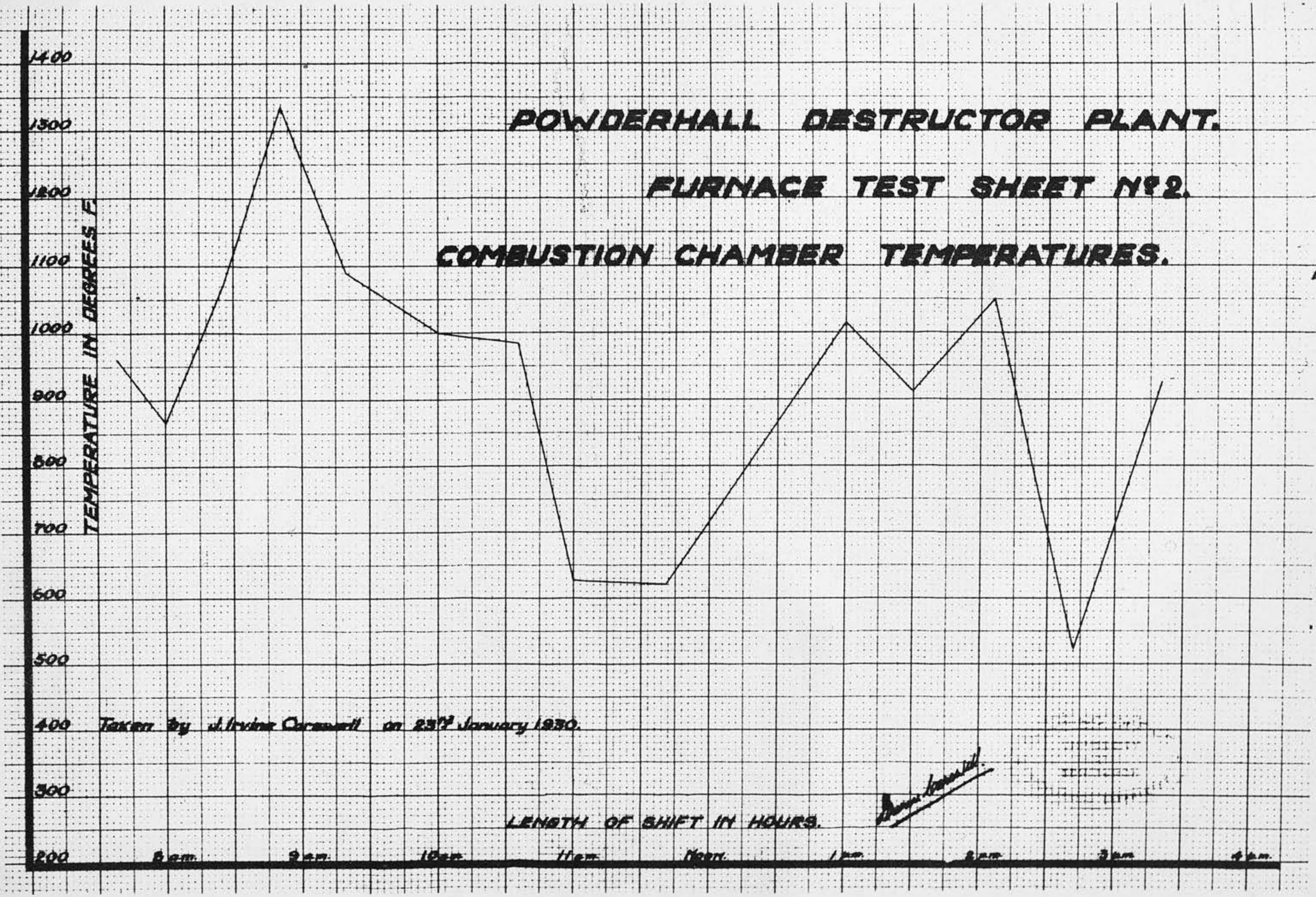
A set of readings was taken at Powderhall extending over one working day and the results plotted (see Test Sheets Nos.1, 2 and 3). The time lag between the readings at different points was due to the shifting of the instrument which was a somewhat cumbersome electrical recording thermometer, reading up to 1500° C.

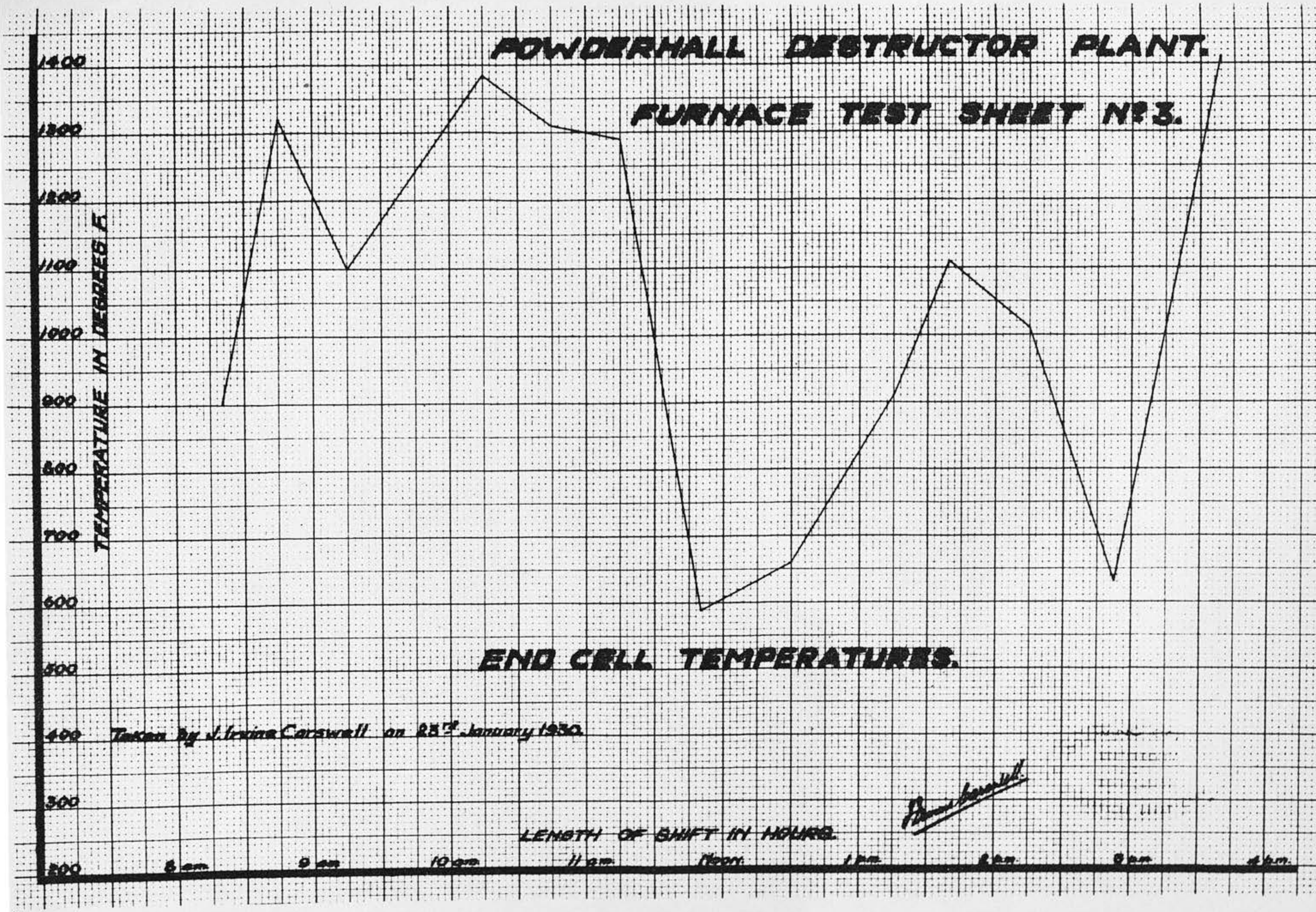
FURNACE OPERATION DURING TEST.

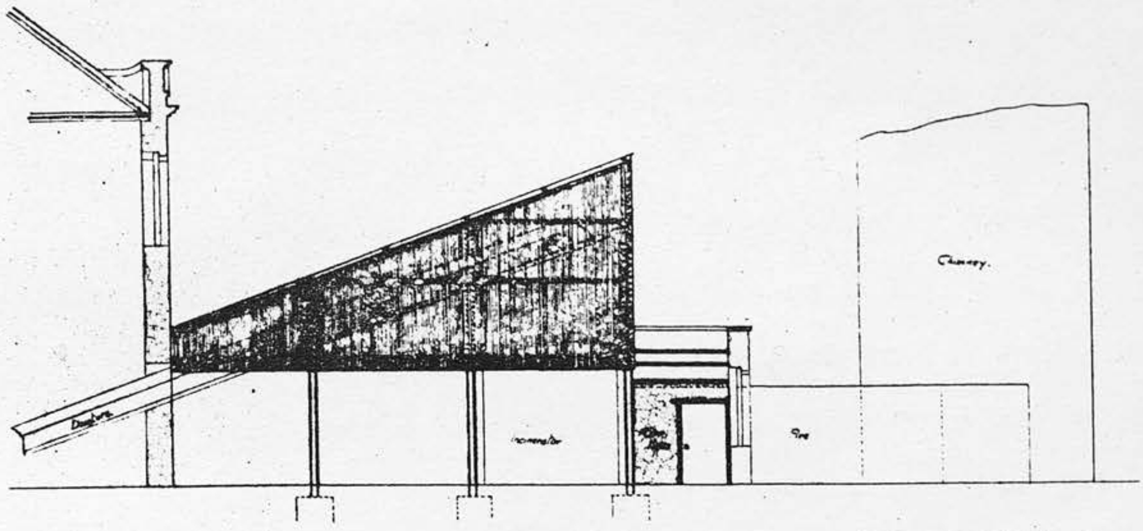
7.40 a.m.	Fire kindled with shavings etc. in one half of furnace and the corresponding unit of the plant started.
8.15 a.m.	2nd Unit started.
10.15 a.m.	1st Unit stopped.
12.30 p.m.	1st Unit re-started.
2.5 p.m.	Blower shut off.
2.15 p.m.	Both Units stopped.
3.5 p.m.	Both Units re-started feeding highly combustible shop refuse into furnace.

The gross input for the day was only 98 ton, 3 cwt. of which 77 ton, 7 cwt. was sent to the bing. The shutting down of half of the plant was necessitated

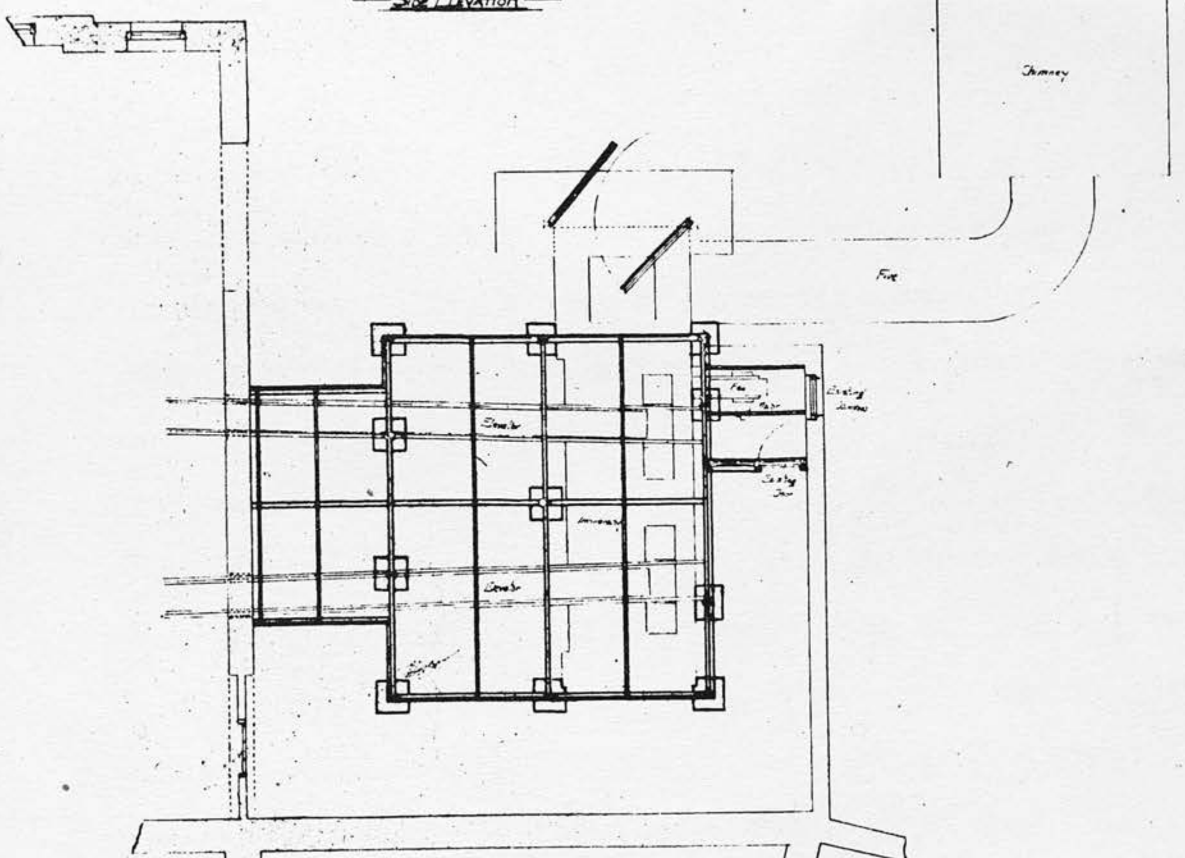

POWDERHALL DESTRUCTOR PLANT.
FURNACE TEST SHEET Nº 1.
CHIMNEY BASE TEMPERATURES.
Taken by J. Irvine Cornwall on 23rd January 1930.
TEMPERATURE IN DEGREES F.
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
LENGTH OF SHIFT IN HOURS.
8 am.
9 am.
10 am.
11 am.
Noon.
1 pm.
2 pm.
3 pm.
4 pm.


POWDERHALL DESTRUCTOR PLANT.
FURNACE TEST SHEET Nº 2.
COMBUSTION CHAMBER TEMPERATURES.
TEMPERATURE IN DEGREES F.
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
Taken by J. Irvine Carswell on 23rd January 1930.
LENGTH OF SHIFT IN HOURS.
8 am.
9 am.
10 am.
11 am.
Noon.
1 pm.
2 pm.
3 pm.
4 pm.


POWDERHALL DESTRUCTOR PLANT.
FURNACE TEST SHEET No 3.
END CELL TEMPERATURES.
Taken by J. Irvine Carswell on 23rd January 1930.
TEMPERATURE IN DEGREES F.
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
LENGTH OF SHIFT IN HOURS.
8 am.
9 am.
10 am.
11 am.
Noon.
1 pm.
2 pm.
3 pm.
4 pm.



SIDE ELEVATION



PLAN

PROPOSED ALTERNATIVE ARRANGEMENT OF HOUSE OVER INCINERATOR AND ELEVATORS

AT POWDERHALL DEPOT

THE CORPORATION OF EDINBURGH

SCALE $\frac{1}{8}$" = 1'0"

14/6/29.

This is one of the Plans referred to in Contracts between the Lord Provost, Magistrates and Council of the City of Edinburgh and us respectively relative to the works shewn on the said Plans.

Irvine Carswell
for Messrs [illegible]

11. 7. 29.

by the arrangement whereby the plant was kept working without break, half the operatives taking their meal hour off, at one time.

The marked temperature changes during working were due to the inrush of cold air when one cell was being clinkered. The rotation employed when both units were in operation was to have two cells under one unit burning (one being fed) while at the other unit one cell had clear fire bars, having recently been clinkered and was being fed, while the remaining cell was being cleaned out.

It will be seen that the chimney base temperature kept below 850° F., a very satisfactory figure, while the furnace end cell only once reached above 1400° F. The chimney was lined with fire brick, with an air space, to a height of about 100 feet and in later years when the plant was required to deal with a considerably increased input, a second lining with air space was added.

The drawings show that two jib cranes were situated over the combustion chamber; these were for feeding large carcases in through the top door. One crane was required to raise the door which weighed 30 cwt., while the other lifted the carcase. The heat proved sufficient to deal with the largest carcase in about half an hour. Small carcases were fed in by hand through the side door.

WASTE PAPER.

This was collected in bags and in 1929 a considerable revenue resulted, the input of 1840 tons of paper realising £3550 after being sorted and baled.

REVENUE FROM SALE OF PAPER.

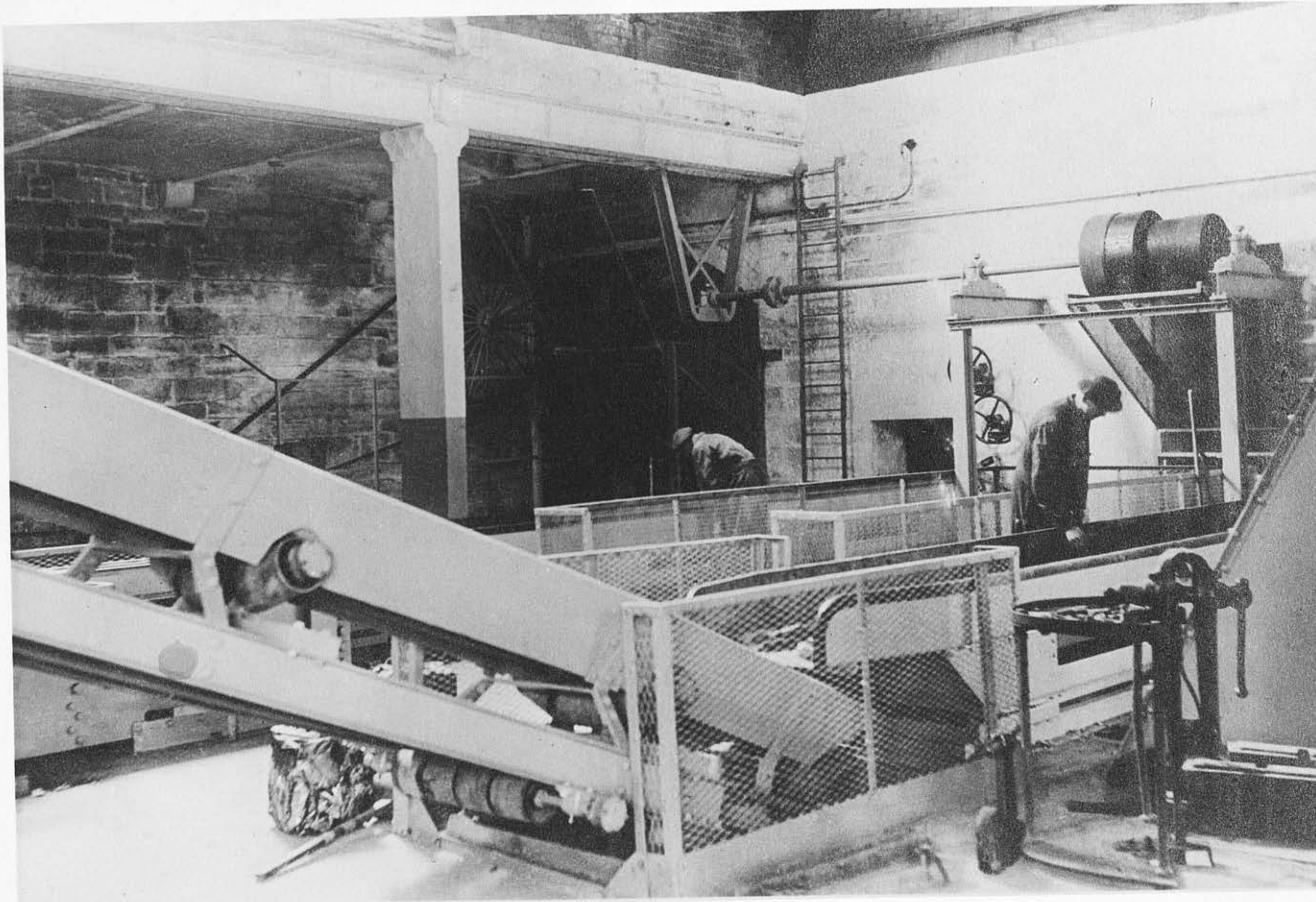
	Weight.		Receipts.		Wages.		Revenue per
	tons.	cwt.	Gross.	per ton.	Gross.	per ton.	ton.
March 1930	178	19	£263	£1·47	£108	£0·604	£0·866
" 1931	133	17	£103	£0·77	£103	£0·77	nil.
" 1932	218	5	£151	£0·693	£118	£0·542	£0·151

From the above it will be seen that the revenue has been deminishing steadily and it requires careful management on the part of the Cleansing Inspector to prevent the paper collection side of town refuse handling becoming a decided liability instead of a possible source of profit.

The different types of paper were sorted out by girls. The prices obtained being so variant that the employment of these sorters has proved economic. The prices shown below give an indication of the wide range and also the decline between 1927 and 1932.

RATES OBTAINED FOR BALED WASTE PAPER /

Plate 18.



Picking House.

RATES OBTAINED FOR BALED WASTE PAPER.

Type.	1927.	1932.
Letters	72/6d. per ton.	42/6d. per ton.
Crushed news	45/-. " "	15/-. " "
Mixed Papers	27/6d. " "	10/-. " "
Buff Paper	115/-. " "	60/-. " "
Brown Paper	62/6d. " "	35/-. " "

One serious complaint resulted from the starting up of the Powderhall plant and this was in connection with nuisance from the chimney. It was observed that under certain conditions of operation the chimney draught was so high that paper, still alight, would rise up the chimney and be carried away a distance of about half a mile. A completely successful remedy was found after some experiment.

In the main flue behind the combustion chamber a wall of fire brick was built, the bricks being laid with spaces between of about 3 inches.

The chimney draught was still sufficiently powerful and by inspection it was found that the checkered wall became hot enough to ensure all paper being completely consumed before passing through a space in the checkerwork and after passing, the sudden increase of area caused a corresponding decrease of velocity which was sufficient to bring about the deposition of all solids on the flue bottom.

Careful inspection was made from neighbouring properties and it was decided that the cure was effective as the only emanissions from the chimney were small quantities of yellow vapour.

The results shown in the annual balance sheet of the Powderhall Plant are moderately good.

The following results are typical of normal working, no reduction being shown for an annual increment from the capital appreciation of the made up ground as this is indeterminate.

WORKING COSTS OF POWDERHALL DESTRUCTOR PLANT.

YEAR ENDING 15th MAY, 1933.

		Screening Plant and Incinerator.	Transport to Dump.	Charges at Dump.
Expenditure.				
Gross		£3242.16. 8	712.19.8	870. 3.7
Revenue.				
Baled Tins recovered	£174. 6. 4			
Non-Ferrous metal	32.11. 9			
Incinerator charges	49. 5.10			
Carcase destruction	29.18. 2	286. 2. 1		
		£2956.14. 7	712.18.8	870. 3. 7

Tonnage. /

Tonnage.

	Tons.	Tons.	Tons.
Screened and Incinerated	30979	-	-
Screened ...	-	19255	19255
Clinker, Ash etc. ...	-	2816	2816
Mud, Sand etc. ...	-	-	4483
Refuse tipped crude ...	-	-	-
Total	30979	22071	26554
Nett cost per ton ...	1/10·9d.	7·75d.	7·05d.
Total cost per ton ...		3/1·17d.	

CONCLUSIONS.

The results shown are as good as can reasonably be expected when the very small revenue account is considered and it is doubtful if they could be improved in any scheme embracing the same principle.

The only method whereby an increased revenue account is possible entails the extraction of heat from the screened refuse and this can only be done by the introduction of more machinery to ensure effective separation and possibly the added complication of some type of vegetable separator to remove the cause of nuisance so that the material can be readily stored.

It is unlikely that a good local market would be obtained but the results from the Falkirk plant demonstrate clearly the very marked economy possible when the Inspector of Cleansing works in close co-operation with the Electricity

Manager.

In Edinburgh the greatest mechanical simplicity was aimed at and at the outset the cost per ton of handling the refuse was remarkably low. The balance sheet given shows the cost under more recent conditions when it was difficult to obtain prices for scrap of any description and naturally the result is not so impressive.

The Grid System of Electric Power transmission throughout the country removes to a very great extent the incentive to experiment in the direction of local economies and in consequence it is doubtful if the method of mixing refuse screenings with washed pearl nuts for fuel in Electricity Generating Stations will be repeated in any future plant.

The method employed at Falkirk, Blackhall and Powderhall for the treatment of town refuse formed the basis of the established type of Refuse handling Plant to be seen in operation at Perth, Dundee and Aberdeen.

21.VIII.36